PROCEEDINGS

OF THE

FIFTEENTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 17, 18 and 19, 1914

VOLUME 15

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CONSTITUTION.

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ARTICLE I.

NAME, OBJECT AND LOCATION.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION. **Name.**

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. **Object.**

3. The means to be used for this purpose shall be as follows: **Means to be Used.**

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) The investigation of matters pertaining to the objects of this Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

4. Its action shall be recommendatory, and not binding upon its members. **Responsibility.**

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city. **Location of Office.**

ARTICLE II.

MEMBERSHIP.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates. **Membership Classes.**

(2) A Member shall be: **Membership Qualifications.**

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership. **Application for Membership.**

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicant shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board. **Election to Membership**

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void. **Subscription to Constitution.**

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction. **Reinstatement.**

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each Member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member. **Honorary Membership.**

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction. **Expulsions.**

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up. **Resignations**

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

OFFICERS.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office. Conditions of Re-election of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected. Term of Officers.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President. Vacancies in Offices.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7. Vacation of Office.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7. Disability or Neglect.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers. Nominating Committee.

(b) The five Members shall be elected annually when the officers of the Association are elected.

2. It shall be the duty of this committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows: Number of Candidates

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be elected at Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman. 3. The Senior Past-President shall act as permanent chairman of the committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee. 4. Prior to December 1st, each year, the Chairman shall call a meeting of the committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees. 5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the Members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members. 6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees. 7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued. 8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names. 9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots. 10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots. 11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls. 12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election. 13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote. 14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article. **Announcement.**

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years, and one for three years. **First Nominating Committee.**

ARTICLE VII.

MANAGEMENT.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee. **Duties of President.**

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction. **Duties of Treasurer.**

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe. **Duties of Secretary.**

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board. **Auditing of Accounts.**

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution. **Duties of Board.**

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board. **Board Meetings.**

7. Seven members of the Board shall constitute a quorum. **Board Quorum.**

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the President, and shall report to and perform their duties under the supervision of the Board of Direction: **Board Committees.**

a. Finance Committee of three members.

b. Publication Committee of three members.

c. Library Committee of three members.

d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof. Notification of Annual Convention.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association. Association Quorum.

5. (a) The order of business at annual conventions of the Association shall be as follows: Order of Business.

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.
New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided. Rules of Order.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak. Discussion.

ARTICLE IX.

AMENDMENTS.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner: Amendments

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are standing committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding annual convention.

Outline of Work.

4. As soon as practicable after each annual convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee work.

6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blue-print. Collection of Data.

7. Committee reports should be prepared as far as practicable to conform to the following general plan: Plan of Reports.

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each annual convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering. Definitions.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given. History.

(f) An analysis of the most important elements of the subject-matter should be given. Analysis.

(g) The advantages and disadvantages of the present and recommended practices should be set forth. Argument.

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles. Illustrations.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions. (i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulæ included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(C) PUBLICATION OF COMMITTEE REPORTS.

Reports Required. 8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each annual convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports. 9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30 of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports. 11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions. 12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions. 13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) CONSIDERATION OF COMMITTEE REPORTS.

Sequence. 14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

15. The method of consideration of Committee reports will be one of the following: **Method.**

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed: **Final Action.**

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION BY TECHNICAL JOURNALS.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL."

Title. 1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding. 3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents. 4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a committee report, published not less than thirty days prior to the annual convention, and submitted by the Committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision. 6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent annual convention, provided such changes are proposed in time for publication not less than thirty days prior to the annual convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each annual convention.

BUSINESS SESSION

PROCEEDINGS.

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its members.

TUESDAY, MARCH 17, 1914.

MORNING SESSION.

The convention was called to order by the President, Mr. Edwin F. Wendt, Member Engineering Board, Interstate Commerce Commission, at 9:30 a. m.

The President—The Fifteenth Annual Convention of the American Railway Engineering Association is declared in session for the transaction of business.

The privilegés of the floor are extended to railway officials who are not members of the Association, and also to professors of institutions of learning, and we will be glad to have them participate in the discussions.

The first business before the convention, in accordance with the Constitution, is the reading of the Minutes of the last Annual Convention. These Minutes have already been printed and distributed to the membership, and unless there is objection, the Minutes will stand approved as printed. There being no objections, the Minutes stand approved as heretofore published.

The next order of business, in accordance with the Constitution, is the reading of the President's address.

PRESIDENT'S ADDRESS.

Fellow Members:

The American Railway Engineering Association continues to grow in membership and usefulness. The past year, 1913, has been characterized by the loyal devotion and conscientious work of members, committees, and Board of Direction.

Conservatism prevails at all times in the conduct of the affairs of the Association.

The committees are endeavoring primarily to accomplish work of quality without reference to its quantity. The membership is awake to the situation, and is working to increase our numbers and influence.

Fifteen years have passed since the organization of our Association. The men who gathered at the first convention, held in Steinway Hall, Chicago, on March 14, 1900, probably had a vision of the future; but the success of our efforts has exceeded even the fondest hopes of those

who organized the Association. They certainly heard a voice, saying, "It doth not yet appear what we shall be." And we hear the same voice to-day, but the question now is, not one of success, but how strong and useful may the Association become.

FINANCE.

The fiscal year of our Association is the same as the calendar year. During 1913 the revenues were $25,878, and the expenditures, $22,347. Therefore, the surplus for the year was $3,531. These figures show that the Association is fairly prosperous; but in order to draw safe deduction, consideration should be given to the relation of revenues to expenses for a period of five years. It will be necessary to reprint the Manual in the near future, at an expense of about $3,500, and the conservative policy of the Board of Direction with reference to the authorization of money for experimental purposes will no doubt prevail until such time as there is a larger revenue.

PUBLICATIONS.

The progress of the work of the Association is reflected in the increase of the text of the Proceedings from 200 pages in 1900 to about 2,000 pages in 1914.

THE MANUAL.

Past-President John F. Wallace, in his address delivered at Steinway Hall, Chicago, March 14, 1900, stated that "The establishment of certain recognized principles as the result of our investigations and discussions, will materially assist our managements in adopting a policy that will lead to the truest and highest economy." The Manual is an expression of these "recognized principles," and the edition of 1911 contains 450 pages of text. The Association should recognize its responsibility for guarding the quality of the work which supports our recommended practice.

WORK OF STANDING COMMITTEES.

The loyal devotion and businesslike methods of the members of our committees have merited the approbation of all well-informed observers of the work of national engineering societies.

MEMBERSHIP.

The growth of the membership in fifteen years has been gradual and consistent. The Constitution definitely defines the qualifications of members, and the standard requirements for entrance result in the selection only of men who possess large education and experience. From about 200 in 1900, the membership has increased to about 1,200 in 1914. It is confidently expected that within ten years the total enrollment will be 2,000. Some of our members feel that it would be safe and profitable to admit to full membership certain classes of engineers who are not

years: An increase in membership is greatly to be desired, in order that the revenues of the Association may be increased. However, the question of money is secondary to that of the qualifications of those who are admitted to full membership.

THE TELEGRAPH AND TELEPHONE.

The work of the Association should be broadened to include the consideration of all elements entering into the fixed physical property. The increasing importance of the telephone in the railway business suggests the advisability of opening our membership to engineers who are expert in the design and construction of telegraph and telephone lines. When a sufficient number of these men join the Association, a special committee on this branch of railroading should be appointed.

RAILS.

The work of our Committee is now recognized by all steam railway carriers, all State Governments and all Federal Governments in America. The improvement of the quality of rails is one of first importance. It is necessary to prosecute the work continuously, and during the past five years the Association has had the practical assistance of the American Railway Association. In order to make more rapid progress in the investigation of the rail problem, the Special Engineer who has been working under the direction of the Rail Committee will be furnished with one expert assistant.

SPECIAL COMMITTEE ON STRESSES IN TRACK.

The Board of Direction has appointed a Special Committee to cooperate with a similar committee from the American Society of Civil Engineers to conduct a series of tests to determine stresses in track. The sum of $10,000 has been tendered to the American Railway Engineering Association by the United States Steel Corporation to aid in defraying the cost of the experiments which will be undertaken. The personnel of our Special Committee is as follows: A. N. Talbot, Chairman; W. M. Dawley, Vice-Chairman; A. S. Baldwin, J. B. Berry, G. H. Bremner, H. E. Hale, John Brunner, W. J. Burton, C. S. Churchill, W. C. Cushing, Dr. P. H. Dudley, Emil Gerber, J. B. Jenkins, Geo. W. Kittredge, P. M. LaBach, Wm. McNab, G. J. Ray, F. E. Turneaure, J. E. Willoughby. The Committee from the A. S. C. E. is the same with the exception of Messrs. Dawley, Hale, LaBach, Dudley and Jenkins.

RAILWAY MECHANICAL ENGINEERING.

The civil engineering departments of railways generally include mechanical as well as civic engineers. Our Constitution states that "a member shall be either a civil engineer, a mechanical engineer, an electrical engineer, etc., etc." Special effort on the part of our members will result in many mechanical engineers making application for admittance,

and the work of the Association will be strengthened and broadened by the selection of a special committee to consider the mechanical features connected with the fixed physical property.

RECORDS AND ACCOUNTS.

The Committee on Records and Accounts during the next five years will consider many important subjects relating to valuation. Greater uniformity of practice in connection with the preparation of engineering records is likely to result from the extension of the powers of the Federal Commission. Our Committee will find it profitable to review the entire question of fundamental records and to determine the forms and methods which make for uniformity.

The work of the Committee should be extended into the field of engineering accounting. The entire series of classifications of accounts of the Interstate Commerce Commission should be carefully studied with reference to both form and principle, and the Association should take a leading part in the discussion of any future changes in these classifications. Engineers have been very backward in taking up the study of cost accounting, but the time has now arrived when the exigencies of the situation demand that engineers in charge of construction and maintenance shall perfect their knowledge of the principles which underlie this important subject.

ORGANIZATION.

The Board of Direction last year requested the Committee on Rules and Organization to begin the study of the science of organization, and report to the Board of Direction how this study can be made profitable to the Association. The Committee has presented to the Board a most excellent report, which will probably be printed in the April Bulletin and distributed to the members. The initial report of the Committee justifies the hope of the Board that this subject can be considered profitably from the standpoint of principle with the greatest benefit to the Association. Efficiency and economy presuppose correct organization. Scientific management is nothing more than the application of correct principles to the management of business, and the study of the principles of organization will be of pronounced educational value to our members.

CONSERVATION OF NATURAL RESOURCES.

During the year the Association was invited to send representatives to the Fifth National Conservation Congress, Washington, D. C., and the following members were appointed as delegates: Messrs. C. H. Fisk (chairman), Earl Stimson, A. W. Carpenter, R. C. Young, and S. B. Rice.

SAFETY.

Invitation was also received to attend the National Conference on Safety and Sanitation, in New York City, and the following members were appointed as delegates: Messrs. C. H. Stein (chairman), Earl Stimson, and H. S. Balliet.

SIGNALS.

At the beginning of the Twentieth Century the efforts of signal experts to establish the economy of signal installations were rewarded. Signals were found to safeguard and facilitate traffic. Each year more and more progress has been made, until to-day signaling is recognized as a prominent factor in successful operation.

The number of automatic block signals and interlocking levers has increased by leaps and bounds, and will continue to increase for many years to come. The mileage of manual block has increased from about 24,000 to 64,555 miles, and that of automatic block from 2,300 to 22,200. Power interlocking has supplanted mechanical machines at nearly all large plants, and the successful operation of such terminals as the Pennsylvania and New York Central at New York, the joint terminals at Boston, St. Louis, and Washington, and that of the Northwestern Railway at Chicago, are due very largely to the development of power interlocking. Three-position signals, electric route-locking, annunciators, electric detector locking as a substitute for detector bars, illuminated track models, and signals working in the upper quadrant, are among the many important improvements which have become indispensable during the life of our Association.

Probably the most interesting development during the past fifteen years has been the use of alternating current for automatic block signaling.

Automatic control of trains has received in the past a large amount of attention by the railways of this Association. The St. Paul had test installations in service when our Association was founded.

Any review of the progress and science of signaling would be incomplete without mention of the earnest and valuable work of Committee X, on Signaling and Interlocking, in their effort to determine a uniform system of signals. For several years the Committee was divided in its opinion, but the members were big enough and broad enough to put aside their individual preference, adopting for their guidance the motto, "Unity in essentials, liberty in non-essentials, charity in all things." Working only for the common good of the profession, they were able last year to present a system which can be universally used, and which has already been adopted on many thousand miles of railway. This system is based on "evolution and not revolution." The adoption of the report of Committee X on uniform signaling by our Association in 1913 marked an epoch in the progress of the railway.

TRACK.

The American Railway Association has requested our Association to co-operate jointly with the Master Mechanics' Association and the Association of Chilled Car Wheel Manufacturers, to determine the question of proper throat clearance for frogs, guard rails and crossings. The work has been assigned to the Committee on Track. Standards of track design, construction and maintenance have been greatly developed during the past 15 years and the work of our Association is to-day regarded as the standard American practice.

ENGLAND INVADES AMERICA.

Henry W. Thornton has been appointed General Manager of the Great Eastern Railway of England. The Chairman of the Board of Directors of the Great Eastern made the following observation:

"We have appointed Henry W. Thornton, of the Long Island, which works under the authority of the Pennsylvania, the premier railroad of the world. His career has been one succession of railroad triumphs and from our point of view there is also the advantage that he has worked on the biggest system of electrically operated suburban traffic in the United States. I know the appointment will be criticised, but I point to the great success which the district railway, which is a part of the London Underground, has had with the importation of Mr. Stanley."

The appointment of Mr. Thornton is a well-merited international recognition of the capacity and ability of American Engineers for the responsible work of management of railway properties.

TERMINALS.

Remarkable progress has been made in the design of terminal stations. The most notable examples completed during the life of our Association are those of the Chicago & Northwestern Railway at Chicago, the Pennsylvania Railroad at New York, and the Grand Central Terminal of the New York Central and Hudson River Railroad at New York City.

Reference has been made by former Presidents to the first two mentioned above. Reference is here made to some of the general features of the Grand Central Station. Between 1903 and the present time the Grand Central Terminal was entirely reconstructed, all old buildings and tracks being removed and replaced with the present magnificent facilities.

To summarize:

RAILROAD	LOCATION
Hudson River Railroad.	Chambers St. and West Broadway.
1st Station in 1851-1871	No. 241 Bowery.
New York & Harlem R. R.	Tyron Row.
1st Station 1832-1839	Madison Avenue 26-27 Sts.
1t Station 1839-1857	Grand Central Terminal.
1st Station 1857-1871	
1st Station 1871	

GRAND CENTRAL TERMINAL

Occupied jointly by the Hudson River Railroad, the New York and Harlem, and the New York, New Haven & Hartford R. R.

1869-1871—Built
1886—Enlarged
1898—Enlarged
1903 to date—Rebuilt

The main Concourse and Waiting Room in the present Terminal were opened for traffic on February 1st, 1913.

The one point which the development of the Grand Central Terminal has demonstrated more than anything else is the fact that in building great terminals in cities where the price of land is very high, a portion of the overhead charges for land can be obtained from the rents of the

"up-air" space or the rental of the "air rights," so-called. The carrier utilizes its sub-surface rights for station purposes and in the case of the Grand Central Terminal has more than 20 entire city blocks where "up-air" rights can be so used as to yield a revenue which will justify the investment in the terminal.

The design of the Grand Central Terminal is one of the most beautiful in the world and from a practical standpoint of adaptability it may be said to have few rivals.

THE ALASKA RAILWAY.

Alaska comprises an area equal to one-fifth of that of the United States. Congress has decided to build not exceeding 1,000 miles of modern railway at an expense not to exceed $35,000,000. The act of Congress permits the President either to operate the road when completed, or to lease it to a private company. The release of the natural resources of Alaska now owned by the Government and the encouragement of private enterprise in the employment of these resources under conditions of governmental regulation which shall fully safeguard the public interests constitutes one of our greatest national problems. The consideration of this new railway marks an epoch in the history of our country in respect to the construction and operation of railways by the Government, but conditions are favorable for the experiment and the results will show whether the new policy of public instead of private ownership is best.

PROGRESS OF CANADA.

During the fifteen years' life of our Association, the Dominion of Canada has made most marvelous progress, which is represented by the rapid growth of its principal transcontinental railway systems.

GRAND TRUNK RAILWAY SYSTEM.

The Grand Trunk Pacific Railway will be completed in 1914. The track is now laid continuous, except over the Quebec bridge, from Moncton, New Brunswick, to Winnipeg, Manitoba, a distance of 1,804 miles, and extends westerly across the Rocky Mountains to a point 1,280 miles west of Winnipeg, making a total continuous mileage from Moncton of 3,084 miles. Tracklaying has been completed from Prince Rupert on the Pacific Ocean, easterly for 325 miles. It is expected that the rails will be connected between the Atlantic and Pacific oceans during the coming summer.

The ports of St. John and Halifax on the Atlantic Ocean are reached from Moncton over the Intercolonial Railway, which is owned and operated by the Canadian Government. The lines of the Grand Trunk Pacific when completed in 1914 will make a system of approximately 5,000 miles of road, and together with the Grand Trunk Railway, which is the parent company, will make a system of lines having a grand total of approximately 10,000 miles.

The enormous resources of the new empire which is now being opened by the Grand Trunk Pacific Railway will guarantee a large traffic for the new line; and in view of the low maximum grade of four-tenths of 1 per cent. through the entire line from ocean to ocean, its traffic will be handled with expedition and economy.

That portion of the road between Moncton and Winnipeg is being built by the Canadian Government under the title of "The National Transcontinental Railway," and when completed, it will be leased to the Grand Trunk Pacific Railway Company for fifty years. The Western Division from Winnipeg to Prince Rupert is being built with the aid of the Grand Trunk Railway Company of Canada and the Canadian Government, the latter guaranteeing the payment of principal and interest of bonds for its construction, to the extent of three-fourths of the cost.

CANADIAN PACIFIC RAILWAY.

The Canadian Pacific Railway was the first transcontinental line in America, and at the present time it owns and operates railway and steamship lines which encircle the globe. The rapid growth and extent of this railway is represented by the following statistics:

Growth of Canadian Pacific Railway

	1899	1913
Mileage of road owned	about 5,500	11,600
Operated over other lines	....	384
Other roads controlled	....	4,604
Under construction	....	1,295
Tons of freight carried 1 mile	2,142,000,000	12,987,000,000
Number of passengers carried 1 mile	431,000,000	1,767,000,000
Total earnings	$26,138,977	$139,395,700
" expenses	15,663,605	93,149,826
" capital stock	65,000,000	200,000,000
" preferred stock	21,000,000	74,000,000
" consolidated debenture stock	....	162,000,000
" cost of road and equipment	214,707,666	452,000,000
" assets	264,000,000	721,000,000

CANADIAN NORTHERN RAILWAY.

Another great transcontinental line is the Canadian Northern Railway, which extends from Quebec to Vancouver, a distance of over three thousand miles.

DEVELOPMENT OF ELECTRIC TRACTION.

During 15 years—1899-1914.

The theoretical possibilities of Electric Traction were recognized so early as 1830 by Thomas Davenport of Vermont.

Following his general theories, others subsequently made experimental demonstrations of electrical car operation.

Dynamos and rotary electric motors were first produced in the early sixties.

In 1887 Frank J. Sprague, who had already made one or two successful Electric Railway installations, undertook the then herculean task of electrifying the entire Street Railway System of Richmond, Va., which project was completed in February, 1888. There were then about a dozen small electric railway systems operated in this country; the most extensive of which had about seven miles of track.

The successful demonstration of Electric Traction made by Sprague at Richmond on a far more extensive scale than had been before accomplished; also the practical development at about this same time of certain essentials to satisfactory and economic operation, gave a great impetus to Street Railway Electrification.

As regards the adaptation of electric traction to heavier classes of service prior to 1900, it can be thus briefly sketched.

So early as 1891, John F. Wallace, then Chief Engineer of the Illinois Central Railroad Company, seriously contemplated and negotiated for the electrification of his company's suburban service at Chicago, which has not yet been undertaken.

In 1892, the Baltimore & Ohio Railroad closed its contract for the electrification of its Belt Line Tunnel at Baltimore, the electrification of which was not completed until 1895.

As early as 1890 the City and South London Underground Tube Railway in England was using small electric locomotives for the haulage of its trains.

In 1896 the New York, New Haven & Hartford Railroad electrified its Nantasket Beach line near Boston; in 1897 and 1898 about forty miles of its branch lines in the vicinity of Hartford, in both instances using heavily equipped motor cars for train haulage.

In 1897 Frank J. Sprague revolutionized all theories previously held on train operation by the invention of his Multiple Unit System of train control, the operative possibilities of which are probably not yet fully appreciated. The Southside Elevated Railroad of Chicago was thus equipped and operated in 1898.

The demonstration there made gave a terrific impetus to the electrification of Elevated Railway and similar roads requiring train service, for the system permitted the distribution of motors throughout the trains and their instant and effective control from one or more points.

Not over one thousand miles of Interurban electric trackage had been constructed prior to 1900. The great development of this class of railways came with the introduction of long distance high tension A. C. current transmission, which did not get fairly under way until about 1900, although Niagara's power was thus transmitted to Buffalo in the latter part of 1896.

Despite this great improvement in methods of transmission, it was several years after 1900 before the practical operation of cars with other than D. C. current at above 600 volts was undertaken.

In 1900 the total track mileage of all electric railways in this country was not far from 20,500, of which, as already stated, not over 1,000 miles was strictly Interurban in its character.

The present track mileage of all American Electric Railways is about 45,000, of which approximately 20,000 miles is Interurban, and on much of which trackage a service comparable to that of Steam Railroads is operated.

At the commencement of 1900 there were not to exceed six types of Electric Locomotive, numbering not above twenty, operated in this country which were of sufficient capacity to be compared with steam locomotives then in use.

There are now in America approximately 151 types representing 463 Electric Locomotives in operation, and 59 on order. Of these approximately 160 are for single or split-phase A. C. operation; 4 for three-phase, and about 100 for D. C. operation at 1,200 volts or higher potential. Of the last about 30 are for operation at 2,400 volts D. C.

These locomotives not in the classes enumerated are for 600 volt operation.

In 1900 about ten 600 volt D. C. locomotives were in operation upon various sections of European steam railroads, as were 12 three-phase.

Up to the present European electrical manufacturers have produced 80 types of electric locomotives to be used by steam railroads, representing 262 machines now in service, and 148 on order.

Of this total probably a third are three-phase; about one-half single-phase and the remainder D. C. Among these last are some high-tension machines.

The form of Electric Traction development since 1900 that has been the most extensive; has replaced far more steam locomotives than has been done by electric locomotives; and that has created a class of railways closely analogous to steam roads, so far as their passenger traffic is concerned, is through the use of heavy cars with a motor capacity of from 300 H.P. to 600 H.P. each.

Probably over 20,000 cars of this general description have been placed in service since 1900. These are operated under such widely varying conditions of service as is represented by caring for the suburban service of the New York Central, Long Island and Southern Pacific Railroads.

That of the Elevated and similar systems.

The electrified portion of the West Jersey & Seashore and similar roads; and by the host of Interurban Electric roads which have heavy traffic or are operated at high speeds.

In Europe there has been but comparatively little construction of Interurban Electric Railways in the sense that the term is used in this country, but much of the steam railroad electrification there is of a character comparable with our practice as regards Interurban electrical equipment and operation.

As regards the use in Europe of heavily-motored cars, such as have just been referred to, there were in operation in 1900 approximately 60

used on underground and similar railways. At the present there are operated there on similar roads and electrified steam roads about 2,800.

In American Interurban Railway development and in Steam Railroad Terminal electrification, high tension D. C. operation at 1,200 volts and above has made great strides since its first introduction in 1907.

It is now installed upon approximately 30 systems aggregating 2,300 miles of track, upon which approximately 715 motor cars and locomotives are operated.

Between 1904 and 1908 an extensive introduction of the single-phase A. C. system of operation occurred in the development on Interurban electrics, which totaled approximately 1,040 miles of track in 1908. Since then D. C. has superseded A. C. on about 430 miles of such trackage. But in 1910 and 1911 there were two single-phase Interurban installations made, aggregating 115 miles of track.

As is well known there is still a strong tendency in certain directions to adopt single-phase locomotives for main-line electrification, and those now in operation and on order have been included in the totals of electric locomotives in America and Europe quoted in the foregoing.

The general tendency in what is termed single-phase development is now toward its material modification, the most important form of which is termed split-phase, such as is now being installed on the Norfolk & Western.

In the development of high tension D. C. operation experiments are being made with so high a potential as 5,000 volts.

Experiments are in progress also with what are termed Mercury Arc Rectifier systems of operation. These are of two different forms.

First—Through the installation of the Mercury Arc Rectifier device of larger sizes than have heretofore been in use, to replace the rotary converters or motor generators which now convert A. C. into D. C. current at substations; and it is hoped by all and expected by a few engineers that practically the same conversion can thus be accomplished without the introduction of moving mechanical parts. This method, if a success, would simplify and reduce the costs of substation operation, but the systems of transmission and distribution, as well as the rolling stock equipment, would remain practically the same as on D. C. roads of the present.

Second—Through the installation of mercury arc rectifiers upon electric locomotives and motor cars, endeavor to secure all the advantages of A. C. transmission and distribution; also to avoid the use of substations for current conversion, yet at the same time thus secure the well-recognized advantages in operation of D. C. motors and control.

Attractive as are the theories involved in both forms of the experiment, apparently great technical difficulties stand in the way of their practical realization.

European experiment and practice in the development of electric traction is along similar lines to those followed in this country, although there is a greater preference there than here for three-phase operation,

probably arising from differences in the physical characteristics of the railroads there as regards the easier and more reliable operation of the distribution circuits working electrical conductors required by the three-phase system.

As is generally known, the Pennsylvania has already arranged for the electrification of a goodly portion of its suburban lines in the vicinity of Philadelphia.

The Chicago, Milwaukee & Puget Sound has contracted for electrical power to operate approximately 450 miles of its main line and are about to order the electrical equipment therefor.

Several other important electrification projects are in immediate contemplation by American railway systems, and electrified sections of railroads are being extended.

Excluding elevated and other local railroad electrifications, about 1,750 miles of steam railroad track has already been electrified and at least 900 miles more has been definitely decided upon; while the electrification of still another 1,000 miles or more is seriously contemplated.

The broad future of railroad electrification is dependent upon its thorough demonstration of great economic advantages over steam. If these are shown, nothing can of course prevent its ultimate general introduction. If these are not so demonstrated, its limitations as regards introduction will soon be reached.

FEDERAL REGULATIONS OF RAILWAYS.

The marvelous development of the system of steam railway transportation has deeply affected the economic and social life of the American people, and has contributed in large measure to the development of the country. Distance is now measured in hours rather than miles. When George Stevenson built and drove the "Rocket" over the Liverpool & Manchester Railway in 1830, the traveller from London to Rome consumed as much time as the courier of Julius Cæsar. The Conestoga wagon in 1790 made the trip from Philadelphia to Pittsburgh in twenty days. The stage coach made the same trip in 1818 in six days. After the construction of the Pennsylvania State Railroad, the train covered the same distance in 1834 in three and one-half days. At present, in 1914, standard passenger trains make the same journey in eight hours. The industrial expansion of the United States, together with the rapid construction and development of railways in all parts of the country, has had a marked effect on the social conditions of the people.

Economics has been defined as the social science of business and the engineer should study the railway business as a problem in economics.

After a public discussion which extended over the years from 1870 to 1885, Congress began the consideration of a law for the regulation of common carriers. Public opinion, both in America and Europe, demanded

that an industry which so vitally affects the comfort and prosperity of the whole people should be subject to public regulation. On February 4, 1887, Congress passed the "Act to Regulate Commerce," which authorized the creation of the Interstate Commerce Commission. This Act contains many provisions, some of which are:

1. Discriminations are prohibited.
2. Railway rates must be reasonable.
3. Rates must be published.
4. The rate for a short haul must not exceed the rate for a long haul under similar circumstances.
5. Pooling contracts are prohibited.

The amendment of 1891 empowered the Commission to subpœna witnesses and require testimony. The act was amended in 1903 by the passage of the Elkins law; in 1906 by the passage of the Hepburn law; and in 1910 by the Mann-Elkins law. These amendments enlarged the powers of the Commission in several ways:

1. Uniform accounts must be kept by all common carriers in accordance with the orders of the Commission.
2. Carriers and shippers alike are subject to the penalty of fine and imprisonment for granting discriminatory rates.
3. The Commission is authorized to secure injunctions against railroads violating the law.
4. Carriers cannot change their rates except on 30 days' notice to the Commission, and the Commission has power to suspend new rates for 10 months, if necessary, until the reasonableness of the proposed rates is determined.
5. The Commission has power to prescribe what is a reasonable rate.

VALUATION OF COMMON CARRIERS.

On March 1, 1913, Congress passed the Valuation Act, which is Section 19a of the "Act to Regulate Commerce." The Interstate Commerce Commission is authorized and empowered to make a valuation of the property of all common carriers of the United States. The term "common carrier" includes steam railways, electric railways, water lines, express companies, sleeping car companies, pipe line companies, telegraph lines, and telephone lines. The problem of valuation is one of gigantic proportions, because it deals with property which is capitalized at about $20,000,000,000. There is no precedent in any country in the world for this important work. In no other country have valuations ever been made for purposes of regulation. It therefore appears that a new work has been undertaken which will accomplish results of the greatest interest to the people. Important social and economic changes may follow.

The magnitude of the valuation problem is reflected in statistics showing the growth of the railway, the telegraph, and the telephone during the past fifteen years, as follows:

DEVELOPMENT OF RAILWAYS IN THE UNITED STATES

Subject	1900	1911	Gain %
Miles of railway	193,346	244,180	26.3
Miles of track	258,784	362,824	40.2
Number of operating roads	1,067	1,312	22.9
Number of locomotives	37,663	61,327	62.8
Number of cars in passenger service	34,713	49,818	43.5
Number of cars in freight service	1,365,531	2,195,511	60.8
Number of employees	1,017,653	1,669,809	64.1
Compensation of employees, yearly	$577,264,841	$1,208,466,470	109.3
Average yearly pay for employee	$567.25	$723.71	27.5
Number of passengers carried	576,931,251	997,409,882	72.8
Tons of freight carried	583,351,351	1,003,053,893	71.9
Average number of tons per train	270.86	383.10	41.4
Capital stock	$5,845,579,593	$8,470,717,611	44.9
Funded debt	$5,645,455,367	$10,738,217,470	91.9

DEVELOPMENT OF THE TELEPHONE—BELL TELEPHONE SYSTEM IN THE UNITED STATES

Subject	1900	1912	Gain %
Mileage of pole lines	131,538	315,003	139.4
Mileage of wire	1,961,801	14,610,813	644.7
Number of stations	855,911	7,456,074	771.1
Number of employees	37,067	140,789	279.8
Number of exchange connections daily	5,668,986	25,572,345	351.9
Number of toll connections daily	148,528	738,823	397.4
Liabilities—Total outstanding obligations	$194,728,100	$751,178,954	
Assets—Total	$230,225,900	$924,260,818	

DEVELOPMENT OF WESTERN UNION TELEGRAPH COMPANY

Subject	1900	1912	Gain %
Mileage of lines	192,705	220,928	14.6
Mileage of wires	933,153	1,517,317	62.6
Number of offices	22,900	25,392	10.9
Number of messages	63,167,783	90,000,000 (est)	42.5
Receipts	$24,758,570	$42,987,807	73.6
Toll for average message	$0.308	$0.388	26.0

Valuation is a problem involving (1) the law; (2) engineering; (3) accounting; (4) economics. First, the corporation is organized under the law, followed by the construction of the property, the accounting for its cost, and finally, the consideration of the results of its operation.

In 1898, at about the time of the first meeting of those eminent engineers who conceived and organized the American Railway Engineering Association, the Supreme Court of the United States handed down its decision in the Nebraska Rate Case, affirming the principle that "The basis of all calculations as to the reasonableness of rates must be the fair value of the property being used for the public convenience. What the company is entitled to is a fair return upon the value of that which it employs for the public convenience." In the opinion of the Circuit Court in the Nebraska Rate Case, Justice Brewer said, "Now, if the public was seeking to take title to the railroad by condemnation, the present value of the property, and not the cost, is that which it would have to

pay. In like manner, it may be argued that when the legislature assumes the right to reduce rates, the rates so reduced cannot be adjudged unreasonable if under them there is earned by the railroad company a fair interest on the actual value of the property." The Supreme Court in the Consolidated Gas Case, in 1909, said, "We concur with the court below, in holding that the value of the property is to be determined as of the time when the inquiry is made regarding the rates. If the property which legally enters into the consideration of the question of rates has increased in value since it was acquired, the company is entitled to the benefit of such increase." In June, 1913, the Supreme Court decided the Minnesota Rate Case, and said: "The property is held in private ownership, and it is that property, and not the original cost of it, of which the owner may not be deprived without due process of law."

A duty will rest upon engineers in connection with this valuation work, because it is necessary to determine the cost of reproduction, which is distinctively an engineering problem. Congress has ordered, "That the Interstate Commerce Commission shall investigate, ascertain, and report the value of all the property owned or used by every common carrier subject to the provisions of this Act. The Commission shall make an inventory which shall list the property of every common carrier . . . . in detail, and show the value thereof, ... and shall classify the physical property, as nearly as practicable, in conformity with the classification of expenditures for road and equipment as prescribed by the Interstate Commerce Commission." The Commission is required among other things to ascertain and report in detail as to each piece of property (1) the original cost to date; (2) the cost of reproduction new; (3) the cost of reproduction less depreciation; and (4) in like manner, other values and elements of value.

ORIGINAL COST TO DATE.

It is probable that the original cost of many railways cannot readily be ascertained, because records have been lost or burned or destroyed. Roads built before the passage of the Hepburn Act, in 1906, kept their accounts in accordance with different accounting systems, and charges to capital were determined by a variety of principles. Uniformity of method in accounting was unknown, and where additions and betterments were made, the cost was divided between operation and investment according to the economic principle which was adopted by a particular carrier.

Railways constructed since July 1, 1907, have been required by the Interstate Commerce Commission to report their investments in accordance with a uniform system of accounts, by which charges to capital account were determined on the basis of a uniform principle. The original cost of these roads can probably be determined.

The determination of the "original cost to date" of railways, whether built before or after the passage of the Hepburn law, is largely an ac-

counting problem. However, many difficulties will arise in connection with the preparation of a final inventory, and it is probable that a portion of the responsibility will rest on engineers.

COST OF REPRODUCTION NEW.

The Commission is required to determine the cost of reproduction of railways, and the Act specifically requires that a detailed inventory shall be prepared, and that the units of the property shall be classified. In order to accomplish this purpose, it will be necessary to remeasure the units of the railways of the country, which, at the present time, amount to about 250,000 miles of road. This is a task of gigantic proportions, involving, as it does, an effort to determine the classified quantities of properties which are estimated to be worth from fifteen to twenty billions of dollars. The work of estimating the "cost of reproduction new" is essentially an engineering problem, and will require the services of many engineers. Many doubtful questions are involved, and since there is no precedent for this work in the history of Europe or America, it will be advisable for such organizations as the American Railway Engineering Association to carefully analyze this problem and study the fundamental principles and factors which should govern.

COST OF REPRODUCTION LESS DEPRECIATION.

The depreciation problem is complex and has a bearing on the determination of "fair value." Considerable study has been given to the depreciation problem, but the principle of depreciation has not heretofore been generally recognized in the keeping of investment accounts. The Supreme Court has decided that depreciation shall be considered, and the problem is to determine the method which will yield a result which will be just and true and fair. This work will involve an extended study on the part of engineers, economists, attorneys and accountants.

OTHER VALUES AND ELEMENTS OF VALUE.

Congress has recognized the fact that valuation is a complex problem, and has ordered that the properties of common carriers shall be investigated and studied in order that "other values, and elements of value, if any, of the property," shall be reported. This work opens up a large field for valuation experts.

KEEPING VALUATIONS UP TO DATE.

Congress has provided that, "Upon the completion of the valuation herein provided for, the Commission shall thereafter in like manner keep itself informed of all extensions or improvements or other changes in the condition and value of the property of all common carriers, and shall ascertain the value thereof, and shall, from time to time, revise and correct its valuation, showing such revision and correction classified, and as a whole and separately in each of the several states and territories and the District of Columbia, which valuations, both original and cor-

rected, shall be tentative valuations and shall be reported to Congress at the beginning of each regular session." All common carriers will be required to report to the Interstate Commerce Commission the details of their investment in each and every extension, improvement, or change, including deductions incident to property which is retired or abandoned. This is a work of great magnitude for construction and maintenance engineers, on whom will rest the responsibility of determining what units of an improvement are to be charged to investment and what units must be charged to operating expenses on account of replacement. Engineering accountants will be required in the offices of original record, and the field of usefulness for the engineer who understands the principles of accounting will be greatly enlarged. Cost accounting is an important branch of railway engineering, and this Association will be justified in requiring its various committees to study the fundamental principles of economics which must be followed in order that the record of cost may be true and fair and just.

SPECIAL COMMITTEE ON VALUATION.

The Board of Direction has considered the appointment of a special committee on valuation of railways, but no final action has been taken. In view of the importance of the work, the Board has arranged to publish a bibliography on the subject, which will be kept up to date by supplements issued from time to time. Many of the fundamental principles and factors entering into valuation remain to be determined, and the high standing of this Association makes it imperative that the membership should lead in the discussion of this question during the next few years. (Applause.)

The President:—The next business is the reading of the reports of the Secretary and Treasurer.

Secretary E. H. Fritch then read the following reports:

SECRETARY'S REPORT.

To the Members of the American Railway Engineering Association:

Your Association is to be congratulated on the progress made during the past year. The interest of the members in the work has been sustained. The increase in membership has been gratifying, and the financial condition is satisfactory.

The Special and Standing Committees are to be complimented on the excellent reports which have been presented for consideration at this meeting. Committee work is often performed at great personal sacrifice of time taken from busy lives, and members of committees deserve credit for their painstaking efforts.

We are also indebted to individual members and others for monographs contributed to the Bulletin from time to time, making valuable information available. This feature can be developed to good advantage,

and members possessing suitable material are urged to present it for publication in the Bulletin.

Another field that can be cultivated to good purpose is that of written discussions of both committee reports and monographs. Up to the present time this feature has been somewhat neglected. Written discussions will undoubtedly be the means of bringing out much useful information.

PUBLICATIONS.

During the year the following publications have been issued:

10 issues of the Bulletin.
1 Volume of the Proceedings.
Supplement to the Manual.
Program and miscellaneous leaflets.

The total number of printed pages issued during the year was 4,198.

On March 29, 1913, the Bulletin of the Association was admitted to the privileges of the second-class mail rates. This permission entitles the publication to be mailed at pound rates, thus effecting a material saving in postage.

Our voluminous Proceedings have demonstrated the need of a General Index, and arrangements have been made to have such Index prepared, covering the fifteen volumes of the annual Proceedings. This work will be undertaken by an Engineer having library experience.

The first edition of the Manual of Recommended Practice was issued in 1905, the second in 1907, and the third in 1911. Supplements thereto have been issued in 1912 and 1913, and the action of this convention will be treated in a similar manner. It would be desirable to republish the Manual in 1915, and with that end in view the efforts of the committees during the coming year should be directed towards perfecting the matter to be embodied in the 1915 Manual.

The demand for the publications of the Association is constantly increasing, and every effort should be made to improve both their quality and appearance.

MEMBERSHIP.

The membership December 31, 1912, was		1,066
Admissions during the year		112
		1,178
Deceased members	6	
Withdrawals during the year	14	
Dropped for nonpayment of dues	11	
	—	31
Total membership December 31, 1913		1,147

GEOGRAPHICAL DISTRIBUTION.

The geographical distribution of members is indicated in the following table:

United States	1,014	Brazil	2
Canada	86	Peru	1
Japan	8	Ecuador	1
Mexico	5	Bolivia	1
Central America	5	Panama	1
New Zealand	4	Porto Rico	1
China	3	Russia	1
Cuba	4	Uruguay	1
Philippine Islands	2	Haiti	1
India	2	Costa Rica	1
Argentine Republic	2	Hawaii	1

Total membership 1,147

INCREASE OF MEMBERSHIP.

Members of the Association can materially assist in increasing the membership by personal effort and suggestions to eligible persons. Members are requested to forward to the Secretary's office the names and addresses of eligible railway officials and others who would make desirable additions to the membership, in order that suitable literature can be furnished.

DECEASED MEMBERS.

The Association has lost by death the following members during the year:

J. C. Haugh, Resident Engineer, New Orleans & Northeastern Railroad.

W. C. Smith, Chief Engineer Maintenance of Way, Northern Pacific Railway.

E. F. Ackerman, Assistant Engineer, Lehigh Valley Railroad.

J. C. Young, Signal Engineer, Union Pacific Railroad.

G. W. West, Civil Engineer.

A. G. Macfarlane, District Engineer, National Transcontinental Railway.

L. R. Zollinger, Engineer Maintenance of Way, Pennsylvania Railroad.

FINANCIAL STATEMENT.

Balance on hand December 31, 1912		$10,745.26
Receipts during the year 1913:		
From members	$13,677.75	
From sales of publications, advertising, etc.	5,577.84	
From Am. Ry. Assn.—Rail Committee expenses	5,627.00	
From interest on bank balance	112.61	
From interest on investments	320.00	
Miscellaneous	563.35	
Total receipts in 1913	$25,878.55	
Expenditures during 1913	22,347.07	
Excess of receipts over expenditures	$ 3,531.48	3,531.48
Balance on hand December 31, 1913		$14,276.74

EXPENDITURES FOR 1913 IN DETAIL.

Stationery and printing	$ 337.12
Proceedings	2,357.34
Bulletins	4,121.19
Manual	384.54
Salaries	4,529.16
Officers' expenses	69.80
Postage	745.55
Telephone and telegrams	74.99
Committee expenses	10.80
Supplies	263.52
Rents	956.63
Expressage	405.17
Light	23.00
Commission on advertising	1,166.75
Annual meeting expenses	918.40
Equipment	64.25
Badges	113.20
Exchange	47.95
Miscellaneous	130.71
Rail Committee expenses	5,627.00
Total	$22,347.07

Your Secretary desires to express his sincere thanks and appreciation to the members of the Association for the courtesy, good-will and consideration extended to him during the past fourteen years.

Respectfully submitted,

E. H. Fritch, *Secretary.*

REPORT OF THE TREASURER.

To the Members of the American Railway Engineering Association:

I have the honor of presenting the following report for the calendar year ending December 31, 1913:

Balance cash on hand December 31, 1912		$10,745.26
Consisting of:		
Cash in bank	$ 5,539.20	
Six railway bonds	5,206.06	
Total	$10,745.26	
Receipts during the year 1913	$25,878.55	
Paid out on audited vouchers	22,347.07	
Excess of receipts over disbursements	$ 3,531.48	3,531.48
Balance on hand December 31, 1913		$14,276.74
Consisting of:		
Six railway bonds, par value $1,000 each, at cost	$ 5,206.06	
Four Lincoln Park bonds, par value $1,000 each, at cost	4,004.27	
Cash in Standard Trust and Savings Bank	5,066.41	
Total	$14,276.74	

The bonds owned by the Association have been registered and placed in a safety deposit box in the Merchants Loan and Trust Company's vaults.

Respectfully submitted,

GEO. H. BREMNER, *Treasurer.*

The Secretary:—The accounts have been audited by Public Accountants, and their figures agree with the foregoing.

(Upon motion, duly carried, the reports of the Secretary and Treasurer were accepted.)

The President:—The next order of business is the reports of Standing and Special Committees. The first Committee on the program is that on Rules and Organization.

It is evident that we have a large amount of business to transact during the three days of the convention, and if the members will be prompt in the discussion, it will facilitate the dispatch of business.

The Chair would suggest that each speaker, on arising to take part in the discussion, that he first state his name and the name of the company or institution with which he is connected, in order that the reporters can get it correctly in the Minutes.

The report of the Committee on Rules and Organization will be presented by the Chairman, Mr. G. D. Brooke, of the Baltimore & Ohio Railroad.

(See report, pp. 65-70; discussion, pp. 1002-1007.)

The President:—In the absence of the Chairman of the Committee on Signals and Interlocking, Mr. Stevens, the report will be presented by the Vice-Chairman, Mr. C. C. Anthony, of the Pennsylvania Railroad.

(See report, pp. 71-100; discussion, pp. 1008-1012.)

The President:—The next report is that of the Committee on Yards and Terminals. In the absence of the Chairman, Mr. Spencer, the report will be presented by the Vice-Chairman, Mr. E. B. Temple, of the Pennsylvania Railroad.

(See report, pp. 101-148; discussion, pp. 1013-1020.)

AFTERNOON SESSION.

The President:—The first report to be taken up this afternoon is that of the Roadway Committee. Mr. W. M. Dawley, of the Erie Railroad, Chairman of the Committee, will present the report.

(See report, pp. 383-400; discussion, pp. 1021-1035.)

The President:—The report of the Committee on Wooden Bridges and Trestles will be presented by the Chairman, Mr. E. A. Frink, of the Seaboard Air Line.

(See report, pp. 401-406; discussion, pp. 1036-1044.)

The President:—The report of the Committee on Iron and Steel Structures will be presented by the Chairman, Mr. A. J. Himes, of the New York, Chicago & St. Louis Railroad.

(See report, pp. 407-511; discussion, pp. 1045-1058.)

WEDNESDAY, MARCH 18, 1914.

MORNING SESSION.

The President:—We will continue the consideration of the report of the Committee on Iron and Steel Structures.

The next report to be considered is that of the Committee on Masonry. Mr. G. H. Tinker, of the New York, Chicago & St. Louis Railroad, Chairman of the Committee, will present the report.

(See report, pp. 513-568; discussion, pp. 1059-1062.)

The President:—Balloting for officers will close at noon to-day, and the Chair will appoint as Tellers Messrs. E. A. Frink, J. C. Nelson, H. S. Wilgus, W. J. Bergen, H. L. Gordon, W. T. Dorrance. The Secretary will turn over the ballots to the Tellers at the close of this morning's session, and they will retire and report to the convention this afternoon before adjournment.

(Vice-President W. B. Storey in the Chair.)

The Vice-President:—The report of the Committee on Track will be presented by the Chairman of the Committee, Mr. J. B. Jenkins, of the Baltimore & Ohio Railroad.

(See report, pp. 569-608; discussion, pp. 1063-1068.)

(President Wendt in the Chair.)

The President:—In the absence of the Chairman of the Committee on Electricity, Mr. Kittredge, the report will be presented by Mr. Harwood, of the New York Central & Hudson River Railroad.

(See report, pp. 609-624; discussion, pp. 1069-1072.)

AFTERNOON SESSION.

The President:—The report of the Committee on Wood Preservation will be presented by the Chairman of the Committee, Mr. Earl Stimson, of the Baltimore & Ohio Railroad.

(See report, pp. 625-682; discussion, pp. 1073-1094.)

The President:—The next report to be considered is that of the Special Committee on Grading of Lumber. The report will be presented by the Chairman, Dr. Hermann von Schrenk.

(See report, page 683; discussion, page 1095.)

The President:—The report of the Committee on Water Service will be presented by the Chairman, Mr. A. F. Dorley, of the Missouri Pacific Railway.

(See report, pp. 685-694; discussion, pp. 1096-1098.)

The President:—The report of the Committee on Buildings will be presented by the Chairman, Mr. Maurice Coburn, of the Vandalia Railroad.

(See report, pp. 705-723; discussion, pp. 1099-1103.)

The President:—The report of the Committee on Rail will be presented by the Chairman, Mr. J. A. Atwood, of the Pittsburgh & Lake Erie Railroad.

(See report, pp. 151-381; discussion, pp. 1104-1120.)

The President:—The Secretary will read the report of the Tellers, appointed to canvass the votes for officers for the coming year.

The Secretary:—The report of the Tellers is as follows:

REPORT OF TELLERS.

To the Members of the American Railway Engineering Association:

We, the undersigned Tellers appointed to canvass the vote for election of officers for 1914, beg to report as follows:

Total vote cast, 721.

President:	
W. B. Storey	704
J. B. Berry	2
A. K. Shurtleff	2
S. B. Fisher	1
Francis Lee Stuart	1
Vice-President:	
A. S. Baldwin	708
C. F. Loweth	1
Treasurer:	
G. H. Bremner	707
W. L. Webb	1
Secretary:	
E. H. Fritch	705
Directors:	
Earl Stimson	394
Curtis Dougherty	280
G. J. Ray	268
C. E. Lindsay	261
John D. Isaacs	251
H. E. Hale	231
R. Montfort	173
J. C. Mock	135
C. H. Stein	122
C. F. W. Felt	1
John G. Sullivan	1
C. A. Wilson	1
L. A. Downs	1
Nominating Committee:	
C Frank Allen	501
John V. Hanna	414
Maurice Coburn	406
J. B. Jenkins	402
C. C. Anthony	366
L. A. Downs	345

J. M. R. Fairbairn	315
G. A. Mountain	305
A. J. Himes	264
C. H. Fisk	109
F. W. Ranno	1
Andrews Allen	1
R. A. Rutledge	1
C. A. Morse	1
M. L. Byers	1
O. E. Selby	1
W. J. Backes	1
J. H. Nuelle	1
R. J. Parker	1
Ralph Budd	1

Respectfully submitted,

(Signed) E. A. Frink,
W. J. Bergen,
H. S. Wilgus,
J. C. Nelson,
W. T. Dorrance,
H. L. Gordon,
Tellers.

The Secretary:—The result of the ballot for officers is as follows:
President—W. B. Storey.
Vice-President—A. S. Baldwin.
Treasurer—G. H. Bremner.
Secretary—E. H. Fritch.
Three Directors (three years each)—Earl Stimson, Curtis Dougherty, G. J. Ray.
Five Members of Nominating Committee—C. Frank Allen, John V. Hanna, Maurice Coburn, J. B. Jenkins, C. C. Anthony.
(Adjournment until 9:30 o'clock Thursday morning.)

THURSDAY, MARCH 19, 1914.

MORNING SESSION.

The President:—The first order of business this morning will be the consideration of the report of the Committee on Ties. The report will be presented by the Chairman, Mr. L. A. Downs, of the Illinois Central Railroad.

(See report, pp. 725-858; discussion, pp. 1121-1136.)

The President:—The next report to be considered is that of the Committee on Signs, Fences and Crossings, Mr. C. H. Stein, of the Central Railroad of New Jersey, Chairman. Mr. Stein will present the report of the Committee.

(See report, pp. 859-904; discussion, pp. 1137-1150.)

The President:—The report of the Committee on Conservation of Natural Resources will be presented by the Chairman, Mr. William McNab, of the Grand Trunk Railway System.

(See report, pp. 905-912; discussion, pp. 1151-1153.)

The President:—In the absence of the Chairman of the Committee on Economics of Railway Location, Mr. R. N. Begien, the report of the Committee will be presented by the Vice-Chairman, Mr. C. P. Howard.

(See report, pp. 912-918; discussion, page 1154.)

The President:—The report of the Committee on Records and Accounts will be presented by the Chairman, Mr. W. A. Christian, of the Chicago Great Western Railway.

(See report, pp. 923-960; discussion, pp. 1157-1161.)

AFTERNOON SESSION.

The President:—The report of the Special Committee on Uniform General Contract Forms will be presented by the Vice-Chairman, Mr. C. A. Wilson, in the absence of the Chairman, Mr. W. G. Atwood.

(See report, pp. 919-921; discussion, pp. 1155, 1156.)

The President:—The last report to be considered is that of the Committee on Ballast. The report will be presented by the Chairman; Mr. H. E. Hale, of the Missouri Pacific Railway.

(See report, pp. 961-1000; discussion, pp. 1162-1166.)

The President:—The reports of Standing and Special Committees having been disposed of, we will take up new business. The Secretary will read some resolutions which he has prepared.

Secretary Fritch:—Mr. President, I desire to offer the following resolutions:

Resolved, by the members of the American Railway Engineering Association, in convention assembled, that we desire to place on record our appreciation and extend our hearty thanks to—

Hon. Charles A. Prouty, Hon. Charles Marcil, and Col. J. M. Schoonmaker, for their admirable and instructive addresses at the annual dinner; to the National Railway Appliances Association for the instructive and comprehensive exhibit of devices used in the construction, maintenance and operation of railways; to the technical press for the daily reports of the convention and the useful information made available to the members; to the official reporters, Messrs. T. E. Crossman and G. W. Burgoyne, for their accurate and painstaking reports of this and previous conventions; to the tellers, Messrs. Frink, Bergen, Gordon, Nelson, Wilgus and Dorrance, for their arduous labors in counting and tabulating the ballots for officers for the ensuing year; to Committee No. "23," on Arrangements, for the highly successful arrangements made for the comfort and entertainment of the members and guests attending this convention, and it is recommended that the Board of Direction grant the Committee a horizontal increase in its "salary." (Applause.)

(The resolutions were adopted unanimously.)

Mr. L. C. Fritch (Canadian Northern):—Mr. President, I desire to offer a resolution:

Resolved, by the members of the American Railway Engineering Association, in convention assembled, that we desire and hereby do give an expression of appreciation of the able manner in which the retiring President, Mr. Edwin F. Wendt, has discharged the duties of President during the past year and presided over the meetings of this convention; that this resolution be spread upon the Minutes and a copy be engrossed and presented to Mr. Wendt.

(The resolution was put to vote by Vice-President Storey and adopted unanimously.)

The President:—Fellow Members; I am sincerely grateful to the members of this Association for the loyal support which they have given to the management of the Association during the past year. Nothing remains to be done now except to install our new President. In handing this gavel over to Mr. Storey, let me say that it has been the emblem of authority here for fifteen years. If the gavel could tell the whole story it would speak of the character and work of the Past-Presidents, Mr. Wallace, Mr. Kittredge, Mr. McDonald, Mr. Johnston, Mr. Kelley, the late Mr. Berg, Mr. McNab, Mr. Fritch, Mr. Cushing and Mr. Churchill.

Fifteen years ago I was present in Steinway Hall at the first convention, and I have attended every convention since. It gives me peculiar pleasure at the present time to say that the management of this Association, in my judgment, is in very safe hands. When you gentlemen come to the time when you will undertake the responsibilities of the presidency of this Association, you will appreciate what it means to be supported by a Board of Direction and a series of committees and a membership such as has supported us during the past year. Without your support the Board of Direction could not accomplish the work which they always do accomplish. Therefore, I wish to impress upon you this one fact: That the Board as well as myself and all other officers recognize that the success which has attended our administration is due entirely to your efforts; and now in presenting the new President, let me say that I know he will receive that same loyal and hearty support that you have given to me and to the other officers. I have nothing but words of encouragement for him, because he will receive the support of all Past-Presidents and of the Secretary, the members of the Board of Direction, the Committee on Arrangements and every member of the Association. Gentlemen, allow me to thank you most sincerely for your loyal support. Now, I take great pleasure in presenting our new President, Mr. Storey, who will be escorted to the platform by Past-President McDonald and Past-President Fritch. (Applause.)

President-Elect Storey: Members of the American Railway Engineering Association; there is very little that I can say at the present time, except to express my deep appreciation of the honor which you have conferred upon me. I consider it a very great honor to be placed in a position of responsibility of this sort, and I can only trust that my incumbency of the office during the coming year will meet with your

approval, and that it may be as efficient as has been that of the President who has just surrendered his gavel to me. There is nothing further that I wish to say to-day. (Applause.)

There are one or two announcements before the meeting is adjourned, which I wish to make. The first is in regard to the Coliseum and the exhibit which is there. To-morrow is set apart for attendance at that exhibit and it is hoped that there will be a large attendance and that we may thus express our appreciation of the efforts made by the railway supply men in connection with this convention.

The Board of Direction, including the new members, will hold a meeting at once after adjournment.

I now declare the Fifteenth Annual Convention adjourned.

(The Sixteenth Annual Convention of the American Railway Engineering Association will be held at the Congress Hotel, Chicago, March 16, 17 and 18, 1915.)

E. H. Fritch, *Secretary*.

COMMITTEE REPORTS

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

G. D. BROOKE, *Chairman;*
R. P. BLACK,
J. B. CAROTHERS,
S. E. COOMBS,
C. DOUGHERTY,
F. D. ANTHONY, *Vice-Chairman;*
K. HANGER,
B. HERMAN,
JOS. MULLEN,
E. T. REISLER,

Committee.

To the Members of the American Railway Engineering Association:

INSTRUCTIONS.

Your Committee on Rules and Organization has worked during the past year under the following instructions:

(1) Review Rules and Instructions heretofore adopted by the Association and recommend such changes and additions thereto as may seem desirable.

(2) Formulate rules for the guidance of field parties:
- (a) When making preliminary surveys for railroad location.
- (b) When making location surveys.
- (c) When in charge of construction.

(3) Begin the study of the Science of Organization, and report to the Board of Direction how this study can be made profitable to the Association.

SUB-COMMITTEES.

Two Sub-Committees were appointed: Sub-Committee A, consisting of:

Curtis Dougherty, Chairman;
J. B. Carothers,
K. Hanger,
Jos. Mullen;

to which was assigned work under instruction (1). Sub-Committee B. consisting of:

B. Herman, Chairman;
S. E. Coombs,
E. T. Reisler,
R. P. Black;

to which was assigned work under instruction (3). Work under instruction (2) was undertaken by the Committee as a whole.

COMMITTEE MEETINGS.

Three meetings of the Committee were held: One at Buffalo on July 11, at which were present: J. B. Carothers, S. E. Coombs, F. D. Anthony, C. Dougherty, Jos. Mullen, E. T. Reisler, G. D. Brooke.

One at Cincinnati on October 17, at which were present: J. B. Carothers, B. Herman, Jos. Mullen, E. T. Reisler. In the absence of the Chairman and Vice-Chairman, Mr. Carothers acted as Chairman of the meeting.

One at Washington on November 29, at which were present: F. D. Anthony, R. P. Black, J. B. Carothers, S. E. Coombs, C. Dougherty, B. Herman, Jos. Mullen, E. T. Reisler, G. D. Brooke.

REVISION OF RULES.

Under instruction (1) the Committee recommends that the following revisions and additions be made in the General Rules for the Government of the Employes of the Maintenance of Way Department, heretofore adopted by the Association:

Add to Rule 4 of "General Notice" the words: "They must familiarize themselves with the safety regulations of the road," making the rule to read:

> "Employes must exercise care and watchfulness to prevent injury to themselves, other employes and the public, and to prevent damage to property. In case of doubt they must take the safe course. They must know that all tools and appliances are in safe condition before using. They must move away from tracks upon approach and during passage of trains, and, so far as practicable, prevent the public from walking on tracks or otherwise trespassing on the right-of-way. They must familiarize themselves with the safety regulations of the road."

Revise Rule 13 under Rules Governing Track Supervisors, Supervisors of Structures and Signal Supervisors, as follows:

> Present Rule: "They must know that foremen are provided with the rules, circulars, forms and special instructions pertaining to their duties, and that they fully understand and comply with them."
>
> Proposed Rule: "They must know that foremen are provided with the rules, circulars, forms, special instructions and safety regulations pertaining to their duties, and that they fully understand and comply with them."

Add a rule under Rules Governing Foremen, to be under Track Foremen No. 18, Bridge and Building Foremen No. 11 and Signal Foremen No. 12, to read:

Add to Rule 17 under Track Foremen:

"They must give special attention to drainage through interlocking plants and where track circuits are used,"

making it read:

"They must keep all interlocking pipe lines and trunking free from grass and weeds, and all switches, frogs and movable parts of interlocking plants free from snow, ice and other obstructions. They must give special attention to drainage through interlocking plants and where track circuits are used."

RULES FOR SURVEY AND CONSTRUCTION WORK.

Under instruction (2) considerable progress has been made in the collection and tabulation of rules and instructions of the various roads bearing on preliminary and location surveys and construction. It is the intention to continue the work during the ensuing year, with the expectation of compiling an extensive set of instructions governing parties engaged in the work described under this instruction.

The following general rules are now presented with the recommendation that they be printed in the Manual:

GENERAL RULES FOR THE GOVERNMENT OF EMPLOYES OF THE CONSTRUCTION DEPARTMENT.

GENERAL NOTICE.

(1) To enter or remain in the service is an assurance of willingness to obey the rules.

(2) The service demands the faithful, intelligent and courteous discharge of duty.

(3) Obedience to the rules is essential to the safety of passengers and employes, and to the protection of property.

(4) Employes must exercise care and watchfulness to prevent injury to themselves, other employes and the public, and to prevent damage to property. In case of doubt they must take the safe course. They must know that all tools and appliances are in safe condition before using. They must move away from tracks upon approach and during passage of trains, and, so far as practicable, prevent the public from walking on tracks or otherwise trespassing on the right-of-way. They must familiarize themselves with the safety regulations of the road.

(5) Employes must do all in their power to prevent accidents, even though in so doing they occasionally perform the duties of others.

(6) Co-operation is required between all employes whose work or duties may be jointly affected.

(7) Anything that interferes with the safe passage of trains at full speed is an obstruction.

(8) Employes in accepting employment assume its risks.

(9) To obtain promotion, capacity must be shown for greater responsibility.

(10) Employes must not absent themselves from duty, exchange duties with others or engage substitutes.

(11) Employes must conduct themselves properly at all times. They will be courteous to fellow-employes and patrons of the road.

ORGANIZATION.

(1) The Construction Department in each........(District or etc.) ....is in charge of the..........(Title).........., who will report to and receive instructions from the............(Title)............

(2) The work of the department will be sub-divided under the following heads:

Preliminary Surveys,	Chief of Party........(or Title)......
Location Surveys,	Chief of Party........(or Title)......
Construction.	Resident Engineer.

RULES GOVERNING CHIEFS OF PARTY ON PRELIMINARY AND LOCATION SURVEYS AND RESIDENT ENGINEERS.

(1) Chiefs of Party / Resident Engineers } will report to and receive instructions from the....................(Title)....................

(2) They are responsible for the prosecution of the work in accordance with the general rules and special instructions, and will make such periodical reports as are required.

(3) They shall keep their parties up to the required strength and report any prospective vacancies to the..............(Title)..............

(4) They are responsible for the proper conduct of the members of their parties and must know that each man is competent to do the work required of him.

(5) They shall conform to the prescribed standards and plans in the execution of work under their charge.

(6) They must keep their parties supplied with the instruments and materials necessary for the efficient performance of their work, and see that these are properly used and cared for.

(7) They must know that instruments are kept in proper adjustment and that the prescribed accuracy is attained in all their work.

(8) They must not give out information as to the object or character of their work and must refer all inquiries to the......(Title)......

(9) They shall keep themselves informed in regard to the work of other survey parties operating in their districts and report to the.........(Title).........anything that will have an influence on their work.

(10) They will assume immediate charge of their parties when running lines and staking out important work.

(11) They must know that their parties are provided with the rules, standards, circulars, forms, special instructions and safety regulations pertaining to their work, and that they are fully understood by the men to whom they apply.

(12) They shall keep a daily journal of the movements of their parties and the work done, and will enter therein current items of information of which it is advisable to keep record.

SCIENCE OF ORGANIZATION.

Under instruction (3) your Committee reports progress in the study of the science of organization, and that a report has been made to the Board of Direction as directed in the instruction.

NEXT YEAR'S WORK.

For next year's work your Committee recommends the following instructions:

(1) Review Rules and Instructions heretofore adopted by the Association and recommend such changes and additions thereto as may seem desirable.

(2) Formulate Rules for the guidance of the Maintenance of Way Department pertaining to Safety.

(3) Continue the formulation of rules for the guidance of field parties:

(a) When making preliminary surveys.

(b) When making location surveys.

(c) When in charge of construction.

(4) Continue the study of the Science of Organization.

Respectfully submitted,

COMMITTEE ON RULES AND ORGANIZATION.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

THOS. S. STEVENS, *Chairman;*
C. C. ANTHONY, *Vice-Chairman;*
AZEL AMES,
H. S. BALLIET,
W. B. CAUSEY,
C. A. CHRISTOFFERSON,
C. E. DENNEY,
W. J. ECK,
W. H. ELLIOTT,
G. E. ELLIS,
M. H. HOVEY,
A. S. INGALLS,
J. C. MOCK,
J. A. PEABODY,
A. H. RUDD,
W. B. SCOTT,
A. G. SHAVER,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee was assigned the following subjects:

(1) Report on economics of labor in signal maintenance.

(2) Formulate and submit requisites for switch indicators, including method of conveying information on condition of the block to conductor and engineman.

(3) Investigate and report on automatic train control.

(1) ECONOMICS OF LABOR IN SIGNAL MAINTENANCE.

In connection with Subject (1) your Committee reports as follows:

Presuming that Signal forces as now organized are efficient generally, the only considerations involved are those of either combining them with other forces which make up a railroad organization, or adding to their duties some of those now undertaken by others. At the start it must be acknowledged that when a certain point is reached signal work involves special training. Under the present social conditions this special training must be given to men with a limited education, must be along practical lines and developed gradually, so that the existing organizations seem to be necessary generally.

The above is true of all departments of a railroad organization, and, therefore, since the men in charge must have the highest training, it seems impracticable to combine the duties of various departments under one foreman. While he might discover that men were actually loafing, he would have little information to guide him in deciding on their efficiency, unless he were trained along the same lines.

It would appear uneconomical to pick out certain bright men and train them to become efficient to supervise a combined force. They must be inefficient at the start in all lines, and to obtain the combined education would prolong this inefficiency and involve more cost than now.

If social conditions made it possible to employ men of higher education as supervisors, the time occupied in acquiring the special knowledge would be less, but the results are problematical. We must know how to do a thing before we can teach others to do it efficiently, and it is not expected that this class of men will be willing to spend a number of years learning the practical details of the several departments. They will specialize because this brings the quickest returns.

Although it appears impossible to effect economy generally by combining maintenance forces, there is territory on nearly every railroad system where the amount of signaling equipment is small and where a combination of duties would be economical. No definite line can be laid down, but this Association can point out the possibilities.

At interlocking plants and manual block stations the local section foreman can be taught to take care of minor mechanical adjustments. In automatic signal territory he can be taught to take care of broken bond wires, the rebonding made necessary on account of broken rails, the adjustment of switches and the maintenance of insulated joints. If these things are done by track forces it might mean extended territory for maintainers.

It is not at all certain that the last suggestion will bring about economy, because it involves assigning duties to track forces which will take them periodically away from their regular work, and it is more than probable that only special cases can be considered. Even testing switches and inspecting bond wires will take time, and if a fair-sized gang is involved may mean loss. When signals fail it becomes necessary to send someone to inspect, and if a handcar only is available this means from two to four men.

So far only track forces have been considered, but we still have bridge and building, water service, telegraph, telephone, electrical and mechanical department forces. Again no definite lines can be laid down. All are trained in some special work which is more or less analagous to different details of signal work, and under favorable conditions it would appear that signal department duties could, with economy, be assigned to local men among these forces.

The assignment of duties of some of the above departments to local signal men should also be considered. Signal work draws men from every class, and a well-advised Superintendent should know that he has a carpenter, mechanical or an electrical worker at some point who can be called on in cases of emergency.

The whole question is local; it seems one which must be handled by each Superintendent probably in different ways on different parts of a division. Granting that the Superintendent is supplied with efficient supervisors for each department of his organization, it is his duty to so arrange them that the greatest economy will result. In this effort he should take counsel with the heads of the different departments to insure that work is not assigned to forces for which they are eminently unfitted.

In signal construction work there is a better field for a co-ordination of division forces. While some of the work is special, much of it is such as other departments are familiar with, and the possibility of maintaining a force of efficient mechanics of all kinds, who will, under the orders of the Superintendent, be used on any class of work, seems to offer a good field for an economical general organization. And so with heavy repairs: If a system of reports were adopted showing work necessary to be done involving different departments, work of the same general character could be assigned to each with a probable large saving.

The result of the adoption of any of the above suggestions cannot be foretold. After all it seems a question for each road to settle. Labor conditions, traffic conditions and climatic conditions are all involved, and an economical practice laid down for one railroad or part of a railroad might be uneconomical for another.

CONCLUSION.

That the report be received as a progress report and the subject continued.

(2) REQUISITES FOR SWITCH INDICATORS.

Your Committee reports progress and asks that the subject be continued. General meetings have been held and earnest discussion given to the indicator situation at these meetings and at the annual convention of the Railway Signal Association. We hope to make final report next year.

(3) AUTOMATIC TRAIN CONTROL.

Your Committee reports as follows:

Because the American Railway Association has appointed a committee consisting of some of the ablest men in the Engineering, Transportation and Mechanical Departments to consider this question, your Committee deems it inadvisable for this Association to undertake work in connection with this subject until report is made by the American Railway Association.

TRACK CIRCUITS.

Because of the growing importance of the track circuit as a controlling agency for all signal appliances, your Committee presents reports of various tests showing the conductivity of creosote and creosote treated ties; also the effect of ballast and bonding conditions.

Future economics of maintenance of track and the construction of refrigerator cars must take into consideration the effect on track circuits or the economies may not be realized.

It is hoped that the cases here given may create interest to the end that further investigation may be made, both with regard to the treated

tie situation and the effect of old ties, which have become porous and therefore subject to moisture penetration.

TESTS OF CREOSOTE USED IN TREATING CROSS-TIES.

Sample 1.—Creosote from Carbondale, Ill.
Sample 2.—Creosote from Somerville, Tex.
Apparatus:

Weston Multimeter Model 58, No. 55. Breakers, glass plates, brass discs, insulated wire, etc.

Method:

Part 1.—Two circular discs of about No. 18 sheet brass were cut to fit into a small beaker. The beaker was 1⅞ in. inside diameter, and the brass discs 1¾ in. in diameter. Each was soldered to a piece of No. 14 solid copper wire, insulated with 1/32-in. rubber wall, and double braid. These discs were suspended in the beaker, one at the bottom and the other one inch above, the separation being maintained by means of two ⅛ in. x 1 in. x 1 in. glass plates on edge. A sample of creosote was then poured into the beaker until the upper disc was entirely submerged. The assembly of apparatus is shown as Fig. 1. A test for resistance between loads A and B was then made by using the multimeter as a Wheatstone bridge. Two samples were tested.

Part 2.—A thin film of creosote was placed on a glass plate and the two brass discs placed firmly in this, on 14-in. centers. The film was two inches wide. An attempt to measure resistance by using Wheatstone bridge resulted in failure, as the resistance was too high. This test is shown in Fig. 2.

Tests:

Part 1.—Sample 1.—Carbondale Creosote.
Measured 90,000 ohms.
Sample 2.—Somerville Creosote.
Measured 80,000 ohms.
Part 2.—Sample 1.—Carbondale Creosote.
Measured in excees of 900,000 ohms.

Data:

	Creosote.	Res. Meas.	Area Discs.	Specif. Res.
1.	Carbondale	90,000	2.41	216,900
2.	Somerville	80,000	2.41	192,800

Specific resistance is per cu. in.

Chemical Analysis:

SAMPLE NO. 1.

Analysis creosote from Carbondale, Ill.:
Specific gravity at 15 degrees C. (60 degrees Fahrenheit)..........1.0450
Specific gravity at 38 degrees C. (100 degrees Fahrenheit)..........1.0720

DISTILLATION.

Water.	Trace.
Up to 200 degrees centigrade	2.2
200 - 210 degrees centigrade	2.0
210 - 235 degrees centigrade	21.1
235 - 270 degrees centigrade	28.6
270 - 315 degrees centigrade	18.8
315 - 355 degrees centigrade	17.7
Residue	9.7
Total per cent	100.1

SAMPLE NO. 2.

Analysis creosote from Somerville, Tex.:

Specific gravity at 38 degrees C. (100 degrees Fahrenheit)	1.0745
Specific gravity at 15 degrees C. (60 degrees Fahrenheit)	1.0929
Weight per gallon at 100 degrees Fahrenheit	8.9505 lbs.
Petroleum oils	None
Tar acids by volume	6 per cent.

DISTILLATION.

Water	2.2
Up to 200 degrees centigrade	.2
200 - 210 degrees centigrade	.8
210 - 235 degrees centigrade	5.7
235 - 270 degrees centigrade	20.2
270 - 315 degrees centigrade	24.6
315 - 355 degrees centigrade	26.1
Residue	19.8
Total per cent	99.6

Specification under which this creosote is purchased is as follows:

The oil to be used must be pure dead oil of coal tar, without adulteration; with a specific gravity of not less than 1.03 at a temperature of 100 Fahrenheit, as compared with water at 60 Fahrenheit, and be thoroughly liquid at 100 Fahrenheit, remaining so on cooling down to 90 Fahrenheit. Up to 170 centigrade nothing should come off; up to 210 centigrade not more than 5 per cent., and up to 235 centigrade not more than 35 per cent. of all products should come off, while not more than 4 per cent. should remain as solid residuum above 335 centigrade; distillation to be conducted under the Von Schrenk method. Not more than 3 per cent. water will be allowed in the oil, and if more than this, the quantity of oil injected must be increased by the total percentage of water found; should the water exceed 6 per cent., further treatment must be suspended until the same has been reduced to a point below the maximum percentage allowed.

Before treatment begins, the Contractor must forward a gallon sample of the oil proposed to be used hereunder, to the Railway Company's Chemist at Somerville, Tex., for analysis, and in case a different oil is thereafter used a new sample must be sent, as above, for further action.

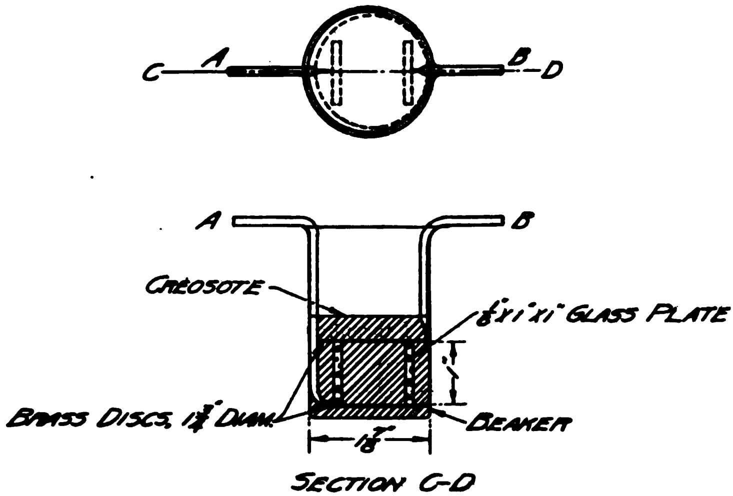


FIG. 1.

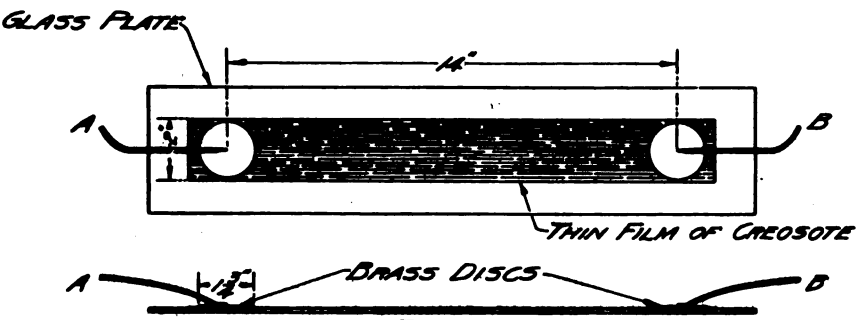


FIG. 2.

TESTS OF CROSS-TIES TREATED WITH CARBONDALE CREOSOTE.

Three smoothly hewn 7 in. x 9 in. x 8 ft. ties, designated hereafter as samples 1, 2 and 3, were tested. These ties have been in the weather, on the Missouri Division for approximately six months, but have not been placed in the track. The pores of these ties seemed to be filled with creosote, but this was not oozing out as sometimes is the case in warm weather. Tests were conducted in laboratory of Engineer of Tests, Topeka. Air was warm and dry.

Apparatus: Weston Multimeter Model 58, No. 55, sections of 90-lb. Santa Fe steel rails, copper bond wires, channel pins, spikes, glass plates. salt (sodium chloride) and hydrant water.

Method: During all resistance measurements ties were insulated from wood and concrete floor by the use of dry glass plates. All leads to multimeter were protected likewise.

Part 1: Five-inch spikes were driven 4½ in. into ties at various distances apart and resistance readings taken. Copper and brass plates were tried for cross-sectional measurements, but without success, as the contact resistance formed too great a proportion of the total. Spikes were driven part way into opposite faces and resistance readings taken.

Part 2: Two sections of 90-lb. Santa Fe rail were firmly spiked at standard gage distance, two spikes being used for each section. Each portion of rail was drilled and No. 8 B. W. G. size copper bond wire bonded thereto. Resistance readings were taken; first, with tie dry; second, after water had been poured over it, and third, after a solution of two pounds common salt had been poured over upper surface of tie and around rail bases. An attempt to read resistance between rail and copper plate placed under tie was not successful on account of high contact resistance.

Tests:

Part 1 (see Fig. 1).

Sample No. 3 dry.
  Spikes 12 in. apart measured 12,000 ohms.
Spikes 4 ft. 8½ in. apart measured 42,000 ohms.
  Cross resistance between spikes 99,000 ohms.
Sample No. 2 dry.
  Spikes 12 in. apart measured 4,200 ohms.
  Spikes 36 in. apart measured 10,000 ohms.
Sample No. 1 wet, and with salt solution on upper surface.
  Spikes 12 in. apart measured 54 ohms.
  Spikes 36 in. apart measured 200 ohms.

Part 2 (see Fig. 2).

Sample No. 1 dry.
  Resistance between rails, 13,000 ohms.
Sample No. 1 after about 1 gal. water had been poured over upper surface and rails.
  Resistance between rails, 12,000 ohms.
Sample No. 1 after more water had been poured over tie.
  Resistance between rails, 11,000 ohms.
Sample No. 1 after the solution of two pounds common salt had been poured over tie.
  Resistance between rails, 1,075 ohms.

Data:

Part 1.

Sample No.	Condition.	Dist. Apart.	Resist. Ohms.
1	Wet-salt	12 in.	54
1	Wet-salt	36 in.	200
2	Dry	12 in.	4,200
2	Dry	36 in.	10,000
3	Dry	12 in.	12,000
3	Dry	4 ft. 8½ in.	42,000
3	Dry	cross	99,000

Part 2.

Sample No.	Condition.	Dist. Apart.	Resist. Ohms.
1	Dry	4 ft. 8½ in.	13,000
1	Wet	4 ft. 8½ in.	12,000
1	Wet	4 ft. 8½ in.	11,000
1	Wet-salt	4 ft. 8½ in.	1,075

Discussion: The results obtained in this experiment would indicate that dry creosoted ties in themselves do not possess very high conductance; nor is their conductance increased to any great extent by the addition of a slight percentage of moisture. The amount of water poured on Sample No. 1 in this test may be assumed as equivalent to a shower on ties in well-drained track. It was impracticable to reproduce conditions experienced in some locations, where the ties may be submerged for hours or days.

The addition of the salt solution brought forth such a great reduction in resistance as to brand this substance as a great detriment to successful track circuit maintenance. While it is assumed that two pounds of salt per tie represents an extreme case, yet the accumulation of brine from refrigerator cars, year after year, may mean that the residue remaining in the tie will eventually approach the amount used in this test.

The cross grain measurement tends to prove that the resistance is less with the grain than along the year rings or radial lines.

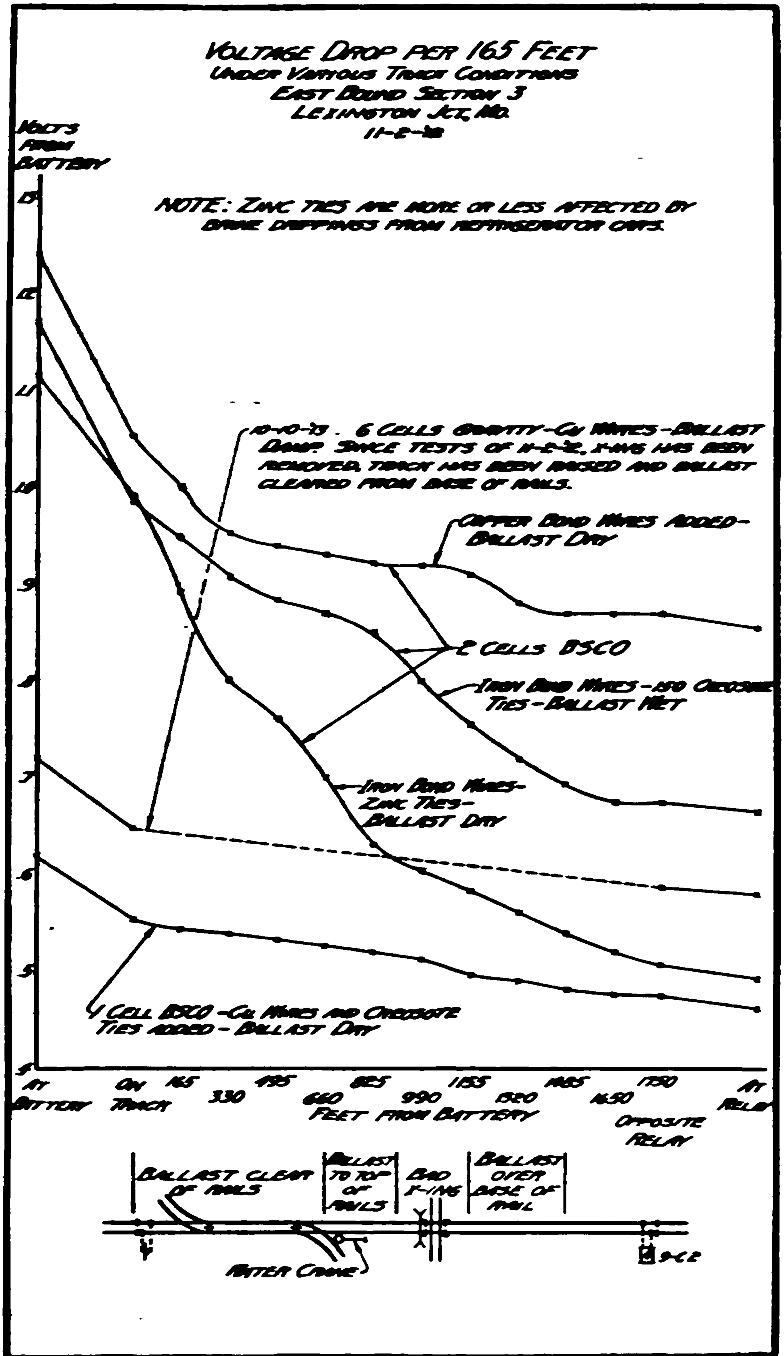
There are approximately 3,200 cross-ties per mile of single track. If all of these possessed the same resistance as the creosote mixture used in treating, and there was leakage of current between rails through no other path, the resultant leakage resistance per mile of track would be 58.7 ohms or 310 ohms per thousand feet.

From the data obtained for Sample No. 1, the following leakage resistances are calculated, it being assumed that all leakage is due to ties alone:

Dry, 4.07 ohms per mile, 21.5 ohms per thousand feet.

Wet, 3.44 ohms per mile, 18.2 ohms per thousand feet.

Salt solution, .336 ohms per mile, 1.77 ohms per thousand feet.


VOLTAGE DROP PER 165 FEET
UNDER VARIOUS TRACK CONDITIONS
EAST BOUND SECTION 3
LEXINGTON JCT. MO.
NOTE: ZINC TIES ARE MORE OR LESS AFFECTED BY BRINE DRIPPINGS FROM REFRIGERATOR CARS.
VOLTS FROM BATTERY
2 CELLS BSCO
COPPER BOND WIRES ADDED - BALLAST DRY
IRON BOND WIRES - ZINC TIES - BALLAST DRY
FEET FROM BATTERY
OPPOSITE RELAY
BALLAST CLEAR OF RAILS
BALLAST TO TOP OF RAILS
BALLAST OVER BASE OF RAIL
WATER CRANE

A measurement of resistance of a man's body, between his hands (moist), was made and found to be 19,000 ohms. Between points on his arms, where skin is thin, the resistance was found to be 10,000 ohms.

FIG. 3.

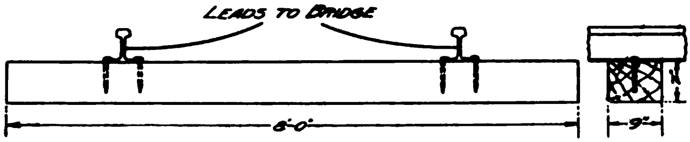


FIG. 4.

REVISION OF MANUAL.

Your Committee has compared the present symbols as shown in the Manual with those at present in use by the Railway Signal Association, and offers the following for the acceptance of the Association as a correction of the present symbols.

CONCLUSION.

That the symbols now shown in the Manual for signals and interlocking be changed in accordance with the Railway Signal Association symbols as shown on following pages.

Respectfully submitted,

COMMITTEE ON SIGNALS AND INTERLOCKING.

PLATE I.

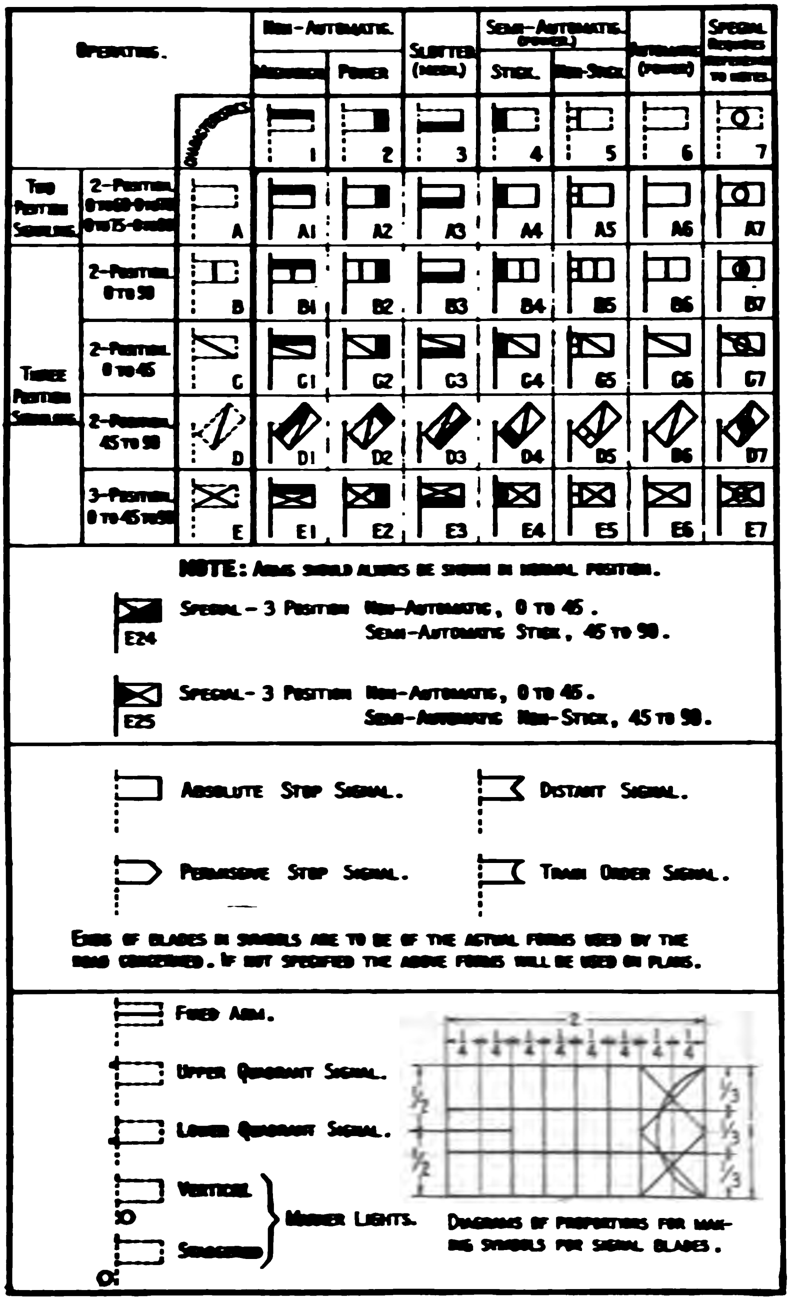

E24
E25
Distant Signal.
Fixed Arm.
Upper Quadrant Signal.
Lower Quadrant Signal.
Marker Lights.

PLATE II.

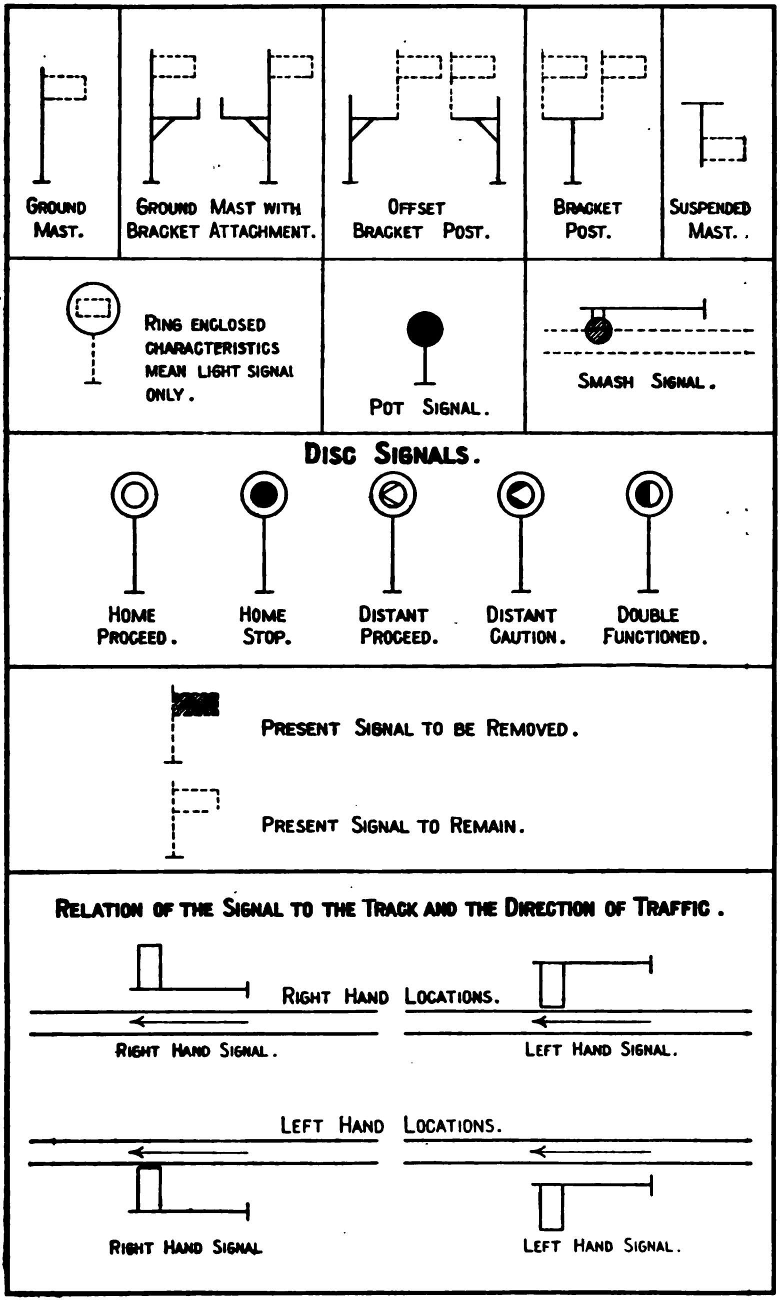

GROUND MAST.
GROUND MAST WITH BRACKET ATTACHMENT.
OFFSET BRACKET POST.
BRACKET POST.
SUSPENDED MAST.
RING ENCLOSED CHARACTERISTICS MEAN LIGHT SIGNAL ONLY.
POT SIGNAL.
SMASH SIGNAL.
DISC SIGNALS.
HOME PROCEED.
HOME STOP.
DISTANT PROCEED.
DISTANT CAUTION.
DOUBLE FUNCTIONED.
PRESENT SIGNAL TO BE REMOVED.
PRESENT SIGNAL TO REMAIN.
RELATION OF THE SIGNAL TO THE TRACK AND THE DIRECTION OF TRAFFIC.
RIGHT HAND LOCATIONS.
RIGHT HAND SIGNAL.
LEFT HAND SIGNAL.
LEFT HAND LOCATIONS.
RIGHT HAND SIGNAL
LEFT HAND SIGNAL.

PLATE III.

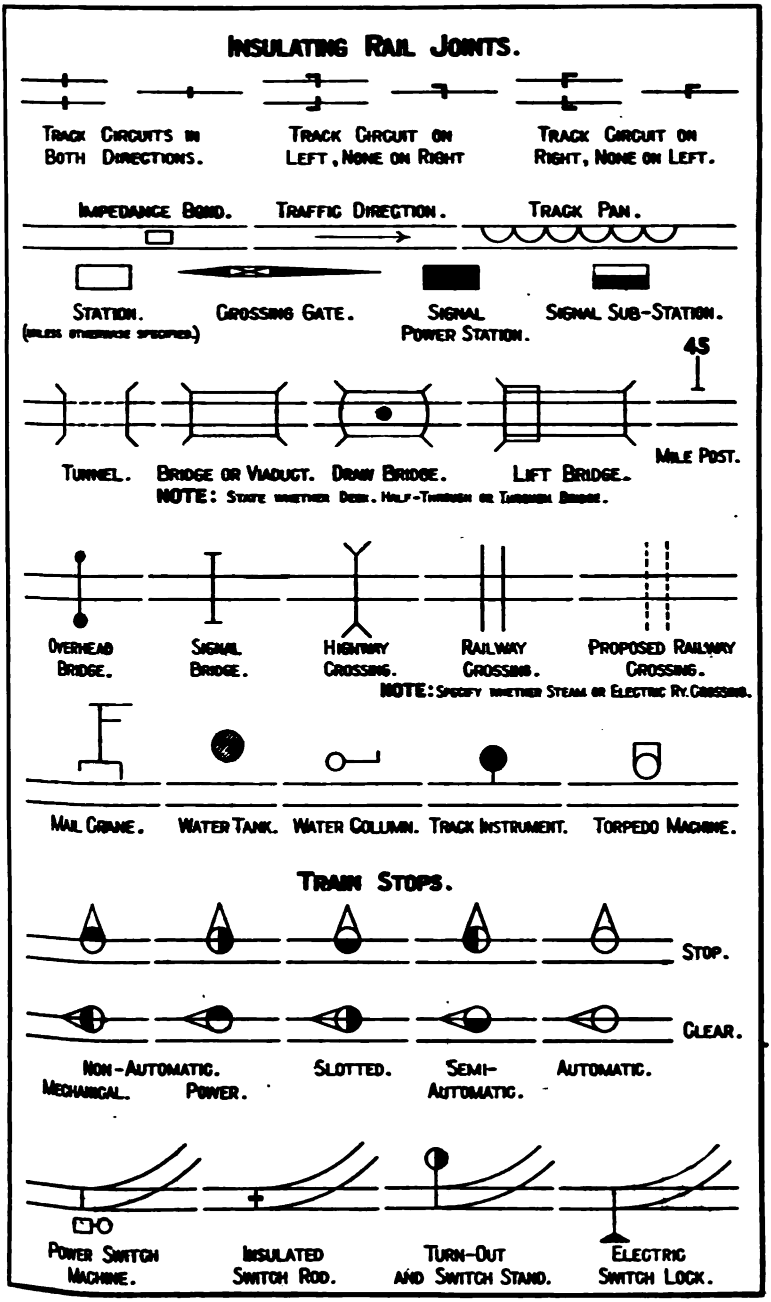

INSULATING RAIL JOINTS.
TRACK CIRCUITS IN BOTH DIRECTIONS.
TRACK CIRCUIT ON LEFT, NONE ON RIGHT
TRACK CIRCUIT ON RIGHT, NONE ON LEFT.
IMPEDANCE BOND.
TRAFFIC DIRECTION.
TRACK PAN.
STATION.
(UNLESS OTHERWISE SPECIFIED)
CROSSING GATE.
SIGNAL POWER STATION.
SIGNAL SUB-STATION.
45
TUNNEL.
BRIDGE OR VIADUCT.
DRAW BRIDGE.
LIFT BRIDGE.
MILE POST.
NOTE: STATE WHETHER DECK, HALF-THROUGH OR THROUGH BRIDGE.
OVERHEAD BRIDGE.
SIGNAL BRIDGE.
HIGHWAY CROSSING.
RAILWAY CROSSING.
PROPOSED RAILWAY CROSSING.
NOTE: SPECIFY WHETHER STEAM OR ELECTRIC RY. CROSSING.
MAIL CRANE.
WATER TANK.
WATER COLUMN.
TRACK INSTRUMENT.
TORPEDO MACHINE.
TRAIN STOPS.
STOP.
CLEAR.
NON-AUTOMATIC.
MECHANICAL.
POWER.
SLOTTED.
SEMI-AUTOMATIC.
AUTOMATIC.
POWER SWITCH MACHINE.
INSULATED SWITCH ROD.
TURN-OUT AND SWITCH STAND.
ELECTRIC SWITCH LOCK.

PLATE IV.

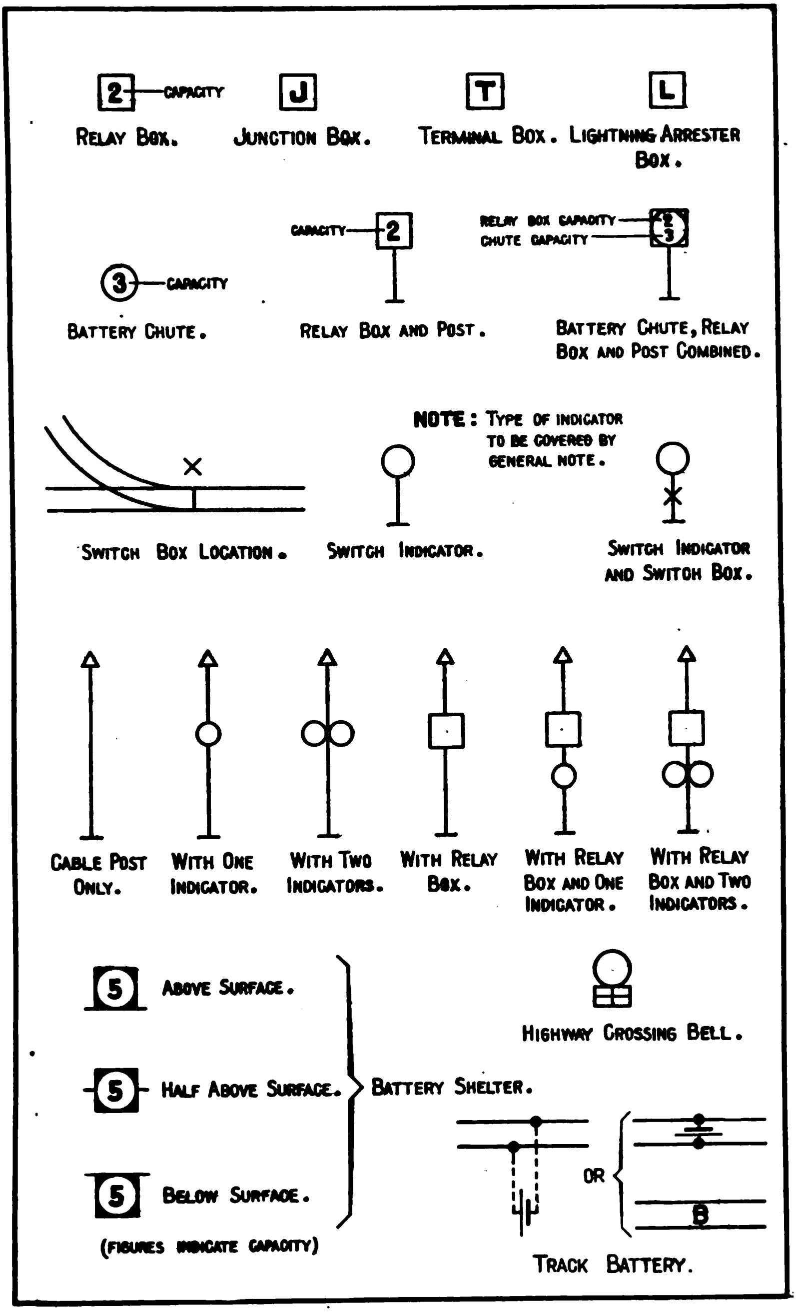

CAPACITY
RELAY BOX.
JUNCTION BOX.
TERMINAL BOX.
LIGHTNING ARRESTER BOX.
CAPACITY
RELAY BOX CAPACITY
CHUTE CAPACITY
CAPACITY
BATTERY CHUTE.
RELAY BOX AND POST.
BATTERY CHUTE, RELAY BOX AND POST COMBINED.
NOTE: TYPE OF INDICATOR TO BE COVERED BY GENERAL NOTE.
SWITCH BOX LOCATION.
SWITCH INDICATOR.
SWITCH INDICATOR AND SWITCH BOX.
CABLE POST ONLY.
WITH ONE INDICATOR.
WITH TWO INDICATORS.
WITH RELAY BOX.
WITH RELAY BOX AND ONE INDICATOR.
WITH RELAY BOX AND TWO INDICATORS.
ABOVE SURFACE.
HALF ABOVE SURFACE.
BELOW SURFACE.
BATTERY SHELTER.
(FIGURES INDICATE CAPACITY)
HIGHWAY CROSSING BELL.
OR
TRACK BATTERY.

PLATE V.

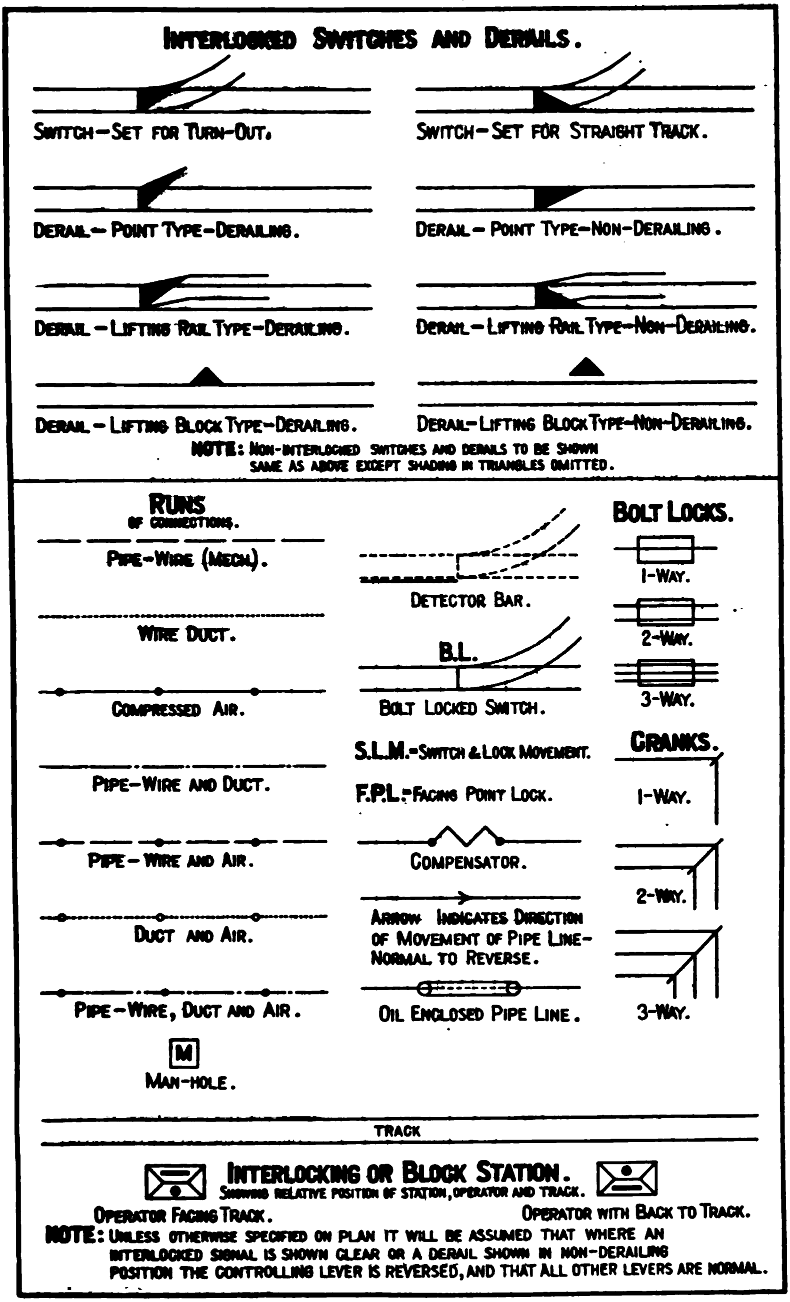

INTERLOCKED SWITCHES AND DERAILS.
SWITCH—SET FOR TURN-OUT.
SWITCH—SET FOR STRAIGHT TRACK.
DERAIL—POINT TYPE—DERAILING.
DERAIL—POINT TYPE—NON-DERAILING.
DERAIL—LIFTING RAIL TYPE—DERAILING.
DERAIL—LIFTING RAIL TYPE—NON-DERAILING.
DERAIL—LIFTING BLOCK TYPE—DERAILING.
DERAIL—LIFTING BLOCK TYPE—NON-DERAILING.
NOTE: NON-INTERLOCKED SWITCHES AND DERAILS TO BE SHOWN SAME AS ABOVE EXCEPT SHADING IN TRIANGLES OMITTED.
RUNS OF CONNECTIONS.
PIPE-WIRE (MECH).
WIRE DUCT.
COMPRESSED AIR.
PIPE-WIRE AND DUCT.
PIPE-WIRE AND AIR.
DUCT AND AIR.
PIPE-WIRE, DUCT AND AIR.
M
MAN-HOLE.
DETECTOR BAR.
B.L.
BOLT LOCKED SWITCH.
S.L.M.=SWITCH & LOCK MOVEMENT.
F.P.L.=FACING POINT LOCK.
COMPENSATOR.
ARROW INDICATES DIRECTION OF MOVEMENT OF PIPE LINE—NORMAL TO REVERSE.
OIL ENCLOSED PIPE LINE.
BOLT LOCKS.
1-WAY.
2-WAY.
3-WAY.
CRANKS.
1-WAY.
2-WAY.
3-WAY.
TRACK
INTERLOCKING OR BLOCK STATION.
SHOWING RELATIVE POSITION OF STATION, OPERATOR AND TRACK.
OPERATOR FACING TRACK.
OPERATOR WITH BACK TO TRACK.
NOTE: UNLESS OTHERWISE SPECIFIED ON PLAN IT WILL BE ASSUMED THAT WHERE AN INTERLOCKED SIGNAL IS SHOWN CLEAR OR A DERAIL SHOWN IN NON-DERAILING POSITION THE CONTROLLING LEVER IS REVERSED, AND THAT ALL OTHER LEVERS ARE NORMAL.

PLATE VI.

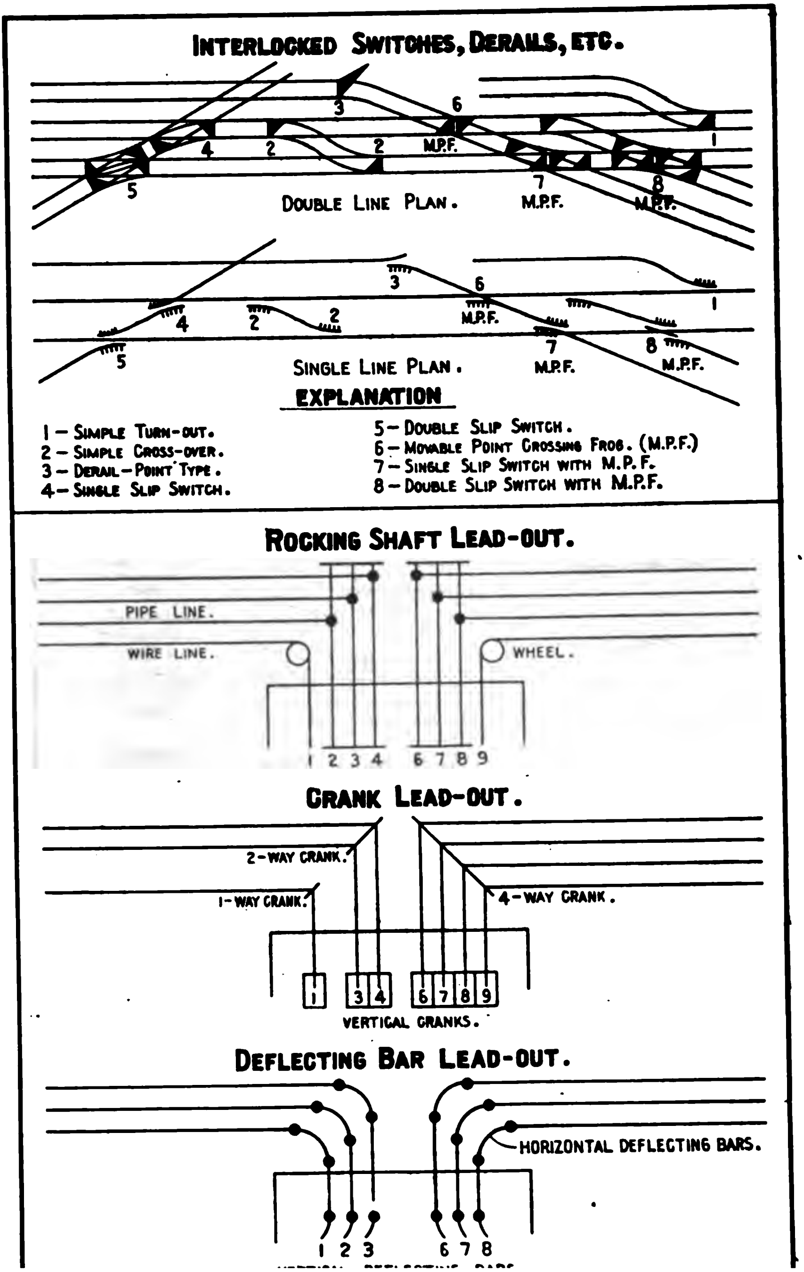
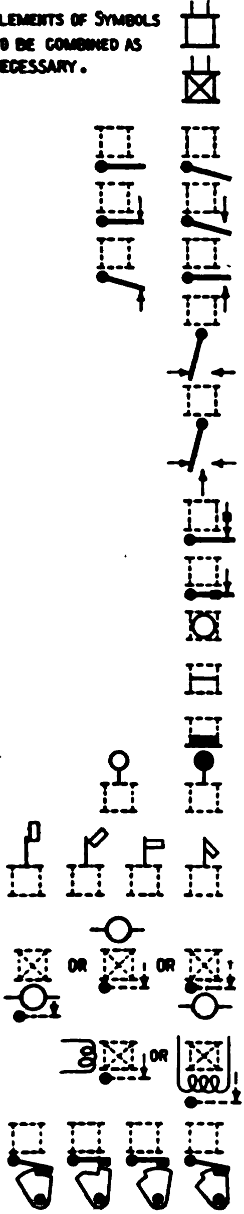

INTERLOCKED SWITCHES, DERAILS, ETC.
DOUBLE LINE PLAN.
M.P.F.
SINGLE LINE PLAN.
EXPLANATION
1 – SIMPLE TURN-OUT.
2 – SIMPLE CROSS-OVER.
3 – DERAIL – POINT TYPE.
4 – SINGLE SLIP SWITCH.
5 – DOUBLE SLIP SWITCH.
6 – MOVABLE POINT CROSSING FROG. (M.P.F.)
7 – SINGLE SLIP SWITCH WITH M. P. F.
8 – DOUBLE SLIP SWITCH WITH M.P.F.
ROCKING SHAFT LEAD-OUT.
PIPE LINE.
WIRE LINE.
WHEEL.
1 2 3 4 6 7 8 9
CRANK LEAD-OUT.
2-WAY CRANK.
1-WAY CRANK.
4-WAY CRANK.
1 3 4 6 7 8 9
VERTICAL CRANKS.
DEFLECTING BAR LEAD-OUT.
HORIZONTAL DEFLECTING BARS.
1 2 3 6 7 8

PLATE VII.

RELAYS, INDICATORS AND LOCKS.

ELEMENTS OF SYMBOLS TO BE COMBINED AS NECESSARY.



D. C. ELECTRO MAGNET.

A. C. ELECTRO MAGNET.

COIL ENERGIZED OR DE-ENERGIZED.

NEUTRAL FRONT CONTACT – CLOSED OR OPEN.

NEUTRAL BACK CONTACT – CLOSED OR OPEN.

POLARIZED ARMATURE – WITH CONTACTS.

3 – POSITION ARMATURE – WITH CONTACTS.

HIGH CURRENT CONTACT.

MAGNETIC BLOW-OUT CONTACT.

BELL ATTACHMENT.

DOUBLE WINDING – SPECIFY IF DIFFERENTIAL.

SLOW ACTING.

DISC TYPE INDICATOR. O = DISC INVISIBLE. ● = DISC VISIBLE.

SEMAPHORE TYPE INDICATOR. = 3-POSITION.

WIRE WOUND ROTOR.

STATIONARY WINDING. = HIGH VOLTAGE WINDING.

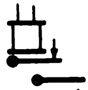
ELECTRIC LOCK – SHOW SEGMENTS FOR LEVER IN NORMAL POSITION.

(SEE NEXT PAGE FOR EXAMPLES OF COMBINATIONS.)

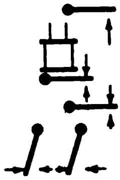
PLATE VIII.

RELAYS, INDICATORS AND LOCKS.

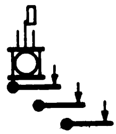
EXAMPLES OF COMBINATIONS.



D.C. RELAY – NEUTRAL – ENERGIZED –
ONE INDEPENDENT FRONT CONTACT CLOSED –
ONE INDEPENDENT BACK CONTACT OPEN.



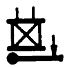
D.C. RELAY – POLARIZED – ENERGIZED –
TWO COMBINATION FRONT AND BACK NEUTRAL CONTACTS –
TWO POLARIZED CONTACTS CLOSED –
TWO POLARIZED CONTACTS OPEN.



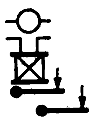
D.C. INDICATOR – SEMAPHORE TYPE – ENERGIZED –
THREE FRONT CONTACTS CLOSED –
BELL ATTACHMENT.

D.G. INDICATOR – SEMAPHORE TYPE – ARM HORIZONTAL –
ENERGIZED – WITHOUT CONTACTS.

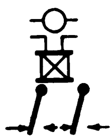
NOTE: INDICATORS (OR REPEATERS) WITHOUT CONTACTS SHOULD BE SHOWN WITH ARMATURES TO INDICATE WHETHER ENERGIZED OR DE-ENERGIZED.



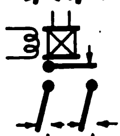
A.C. RELAY – ONE ENERGIZING CIRCUIT TYPE (SINGLE PHASE)
ENERGIZED – ONE FRONT CONTACT.



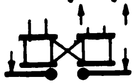
A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO NEUTRAL FRONT CONTACTS.



A.C. RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
WIRE WOUND ROTOR –
TWO POLARIZED CONTACTS.



A.C RELAY – TWO ENERGIZING CIRCUIT TYPE – ENERGIZED –
STATIONARY WINDINGS –
ONE NEUTRAL FRONT CONTACT –
TWO 3-POSITION CONTACTS.



D.C. INTERLOCKED RELAY.

D.C. ELECTRIC BELL.

DESIGNATE RESISTANCE IN OHMS OF ALL D.C. RELAYS, INDICATORS AND LOCKS.

PLATE IX.

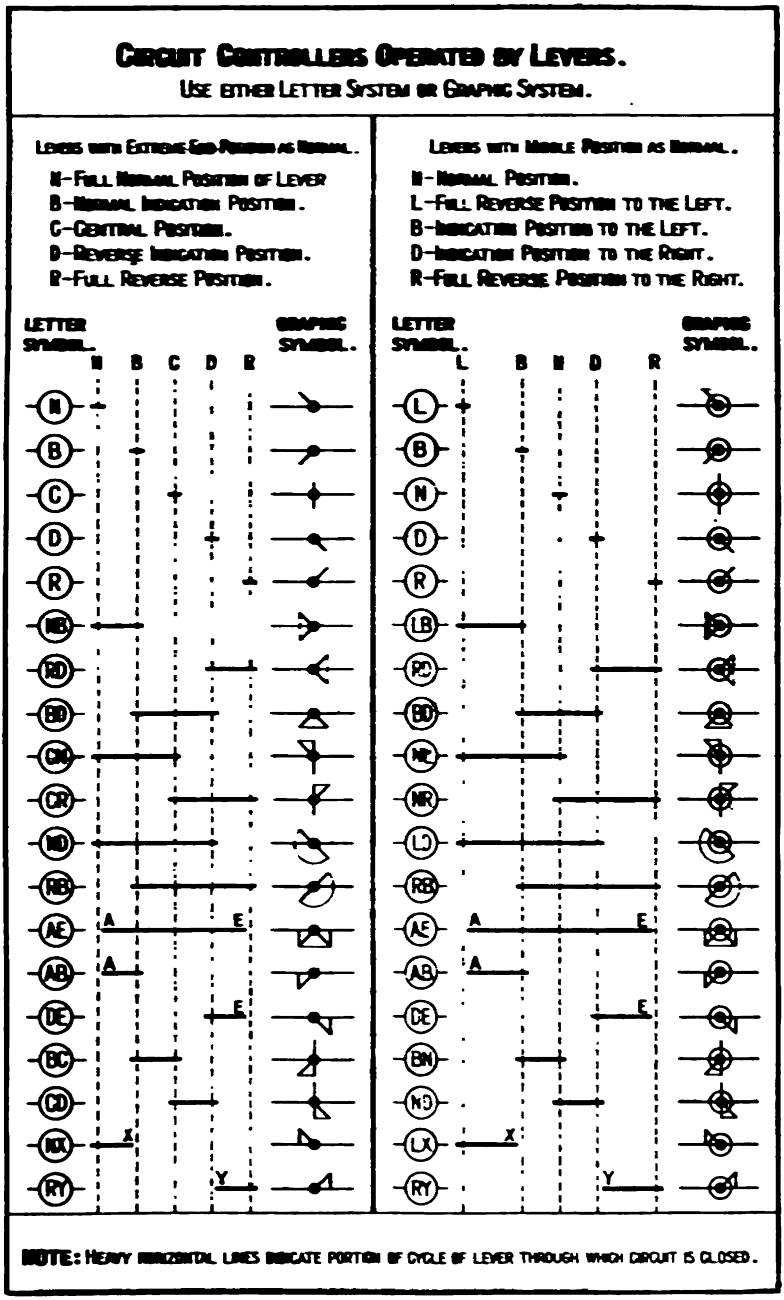

CIRCUIT CONTROLLERS OPERATED BY LEVERS.
USE EITHER LETTER SYSTEM OR GRAPHIC SYSTEM.
LEVERS WITH EXTREME END POSITION AS NORMAL.
N-FULL NORMAL POSITION OF LEVER
B-NORMAL INDICATION POSITION.
C-CENTRAL POSITION.
D-REVERSE INDICATION POSITION.
R-FULL REVERSE POSITION.
LEVERS WITH MIDDLE POSITION AS NORMAL.
N-NORMAL POSITION.
L-FULL REVERSE POSITION TO THE LEFT.
B-INDICATION POSITION TO THE LEFT.
D-INDICATION POSITION TO THE RIGHT.
R-FULL REVERSE POSITION TO THE RIGHT.
LETTER SYMBOL.
GRAPHIC SYMBOL.
N B C D R
L B N D R
N B C D R NB RD BD CN CR ND RB AE AB DE BC CD NX RY
L B N D R LB RD BD NB NR LD RB AE AB DE BN ND LX RY
NOTE: HEAVY HORIZONTAL LINES INDICATE PORTION OF CYCLE OF LEVER THROUGH WHICH CIRCUIT IS CLOSED.

PLATE X.

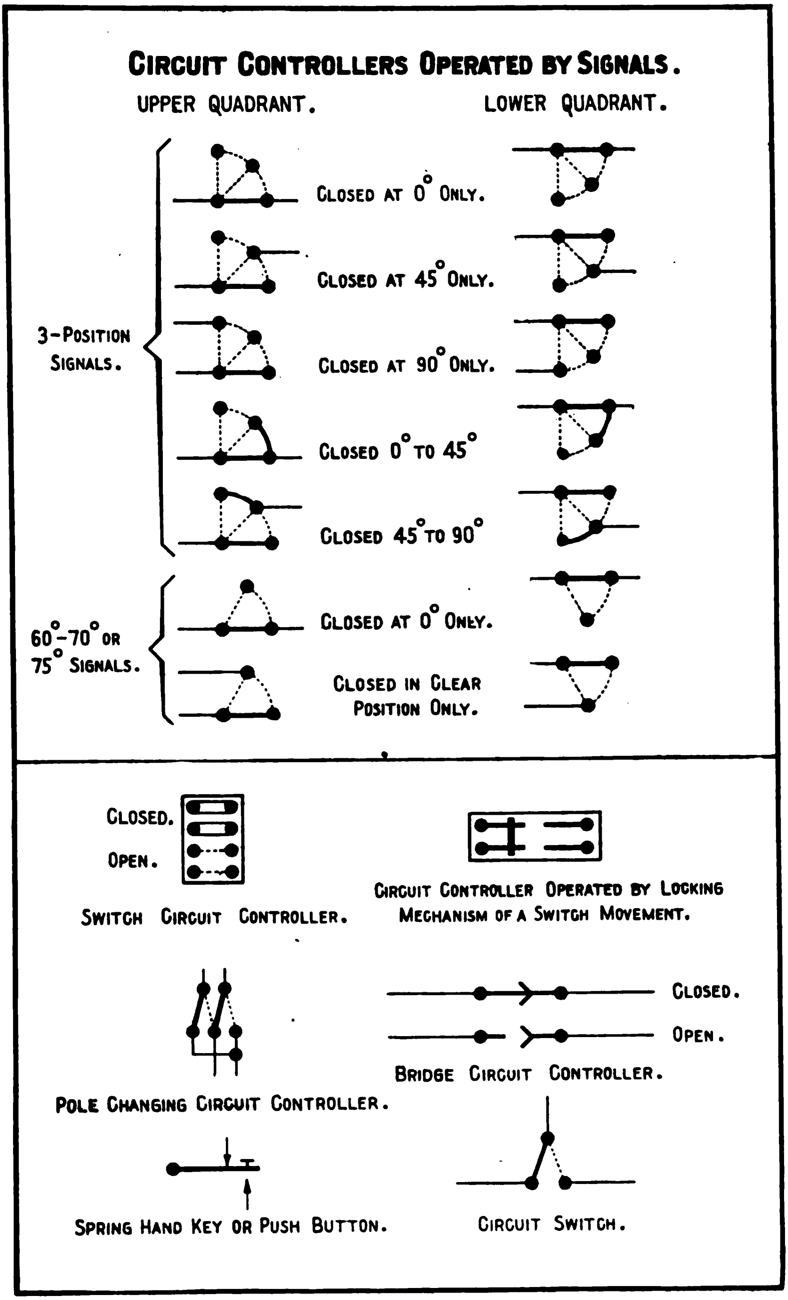

CIRCUIT CONTROLLERS OPERATED BY SIGNALS.
UPPER QUADRANT.
LOWER QUADRANT.
3-POSITION SIGNALS.
CLOSED AT 0° ONLY.
CLOSED AT 45° ONLY.
CLOSED AT 90° ONLY.
CLOSED 0° TO 45°
CLOSED 45° TO 90°
60°-70° OR 75° SIGNALS.
CLOSED AT 0° ONLY.
CLOSED IN CLEAR POSITION ONLY.
CLOSED.
OPEN.
SWITCH CIRCUIT CONTROLLER.
CIRCUIT CONTROLLER OPERATED BY LOCKING MECHANISM OF A SWITCH MOVEMENT.
CLOSED.
OPEN.
BRIDGE CIRCUIT CONTROLLER.
POLE CHANGING CIRCUIT CONTROLLER.
SPRING HAND KEY OR PUSH BUTTON.
CIRCUIT SWITCH.

PLATE XI.

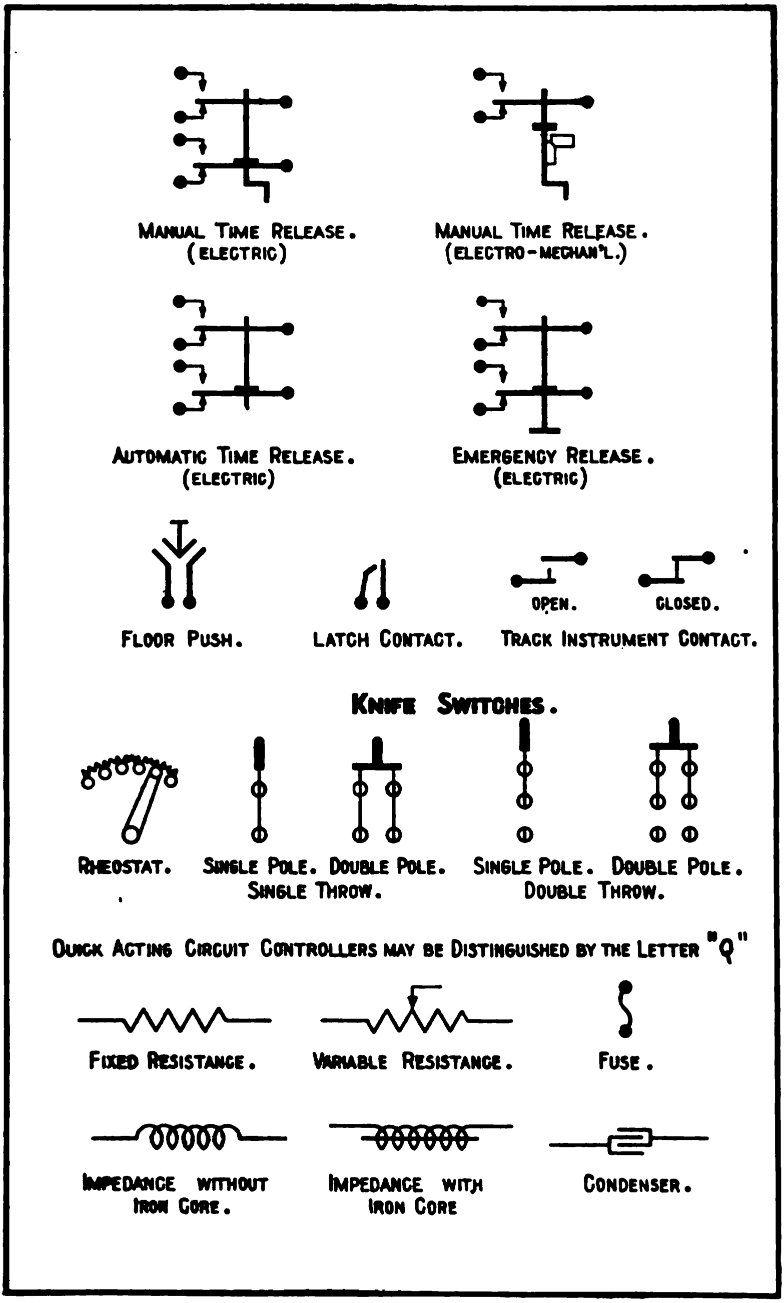
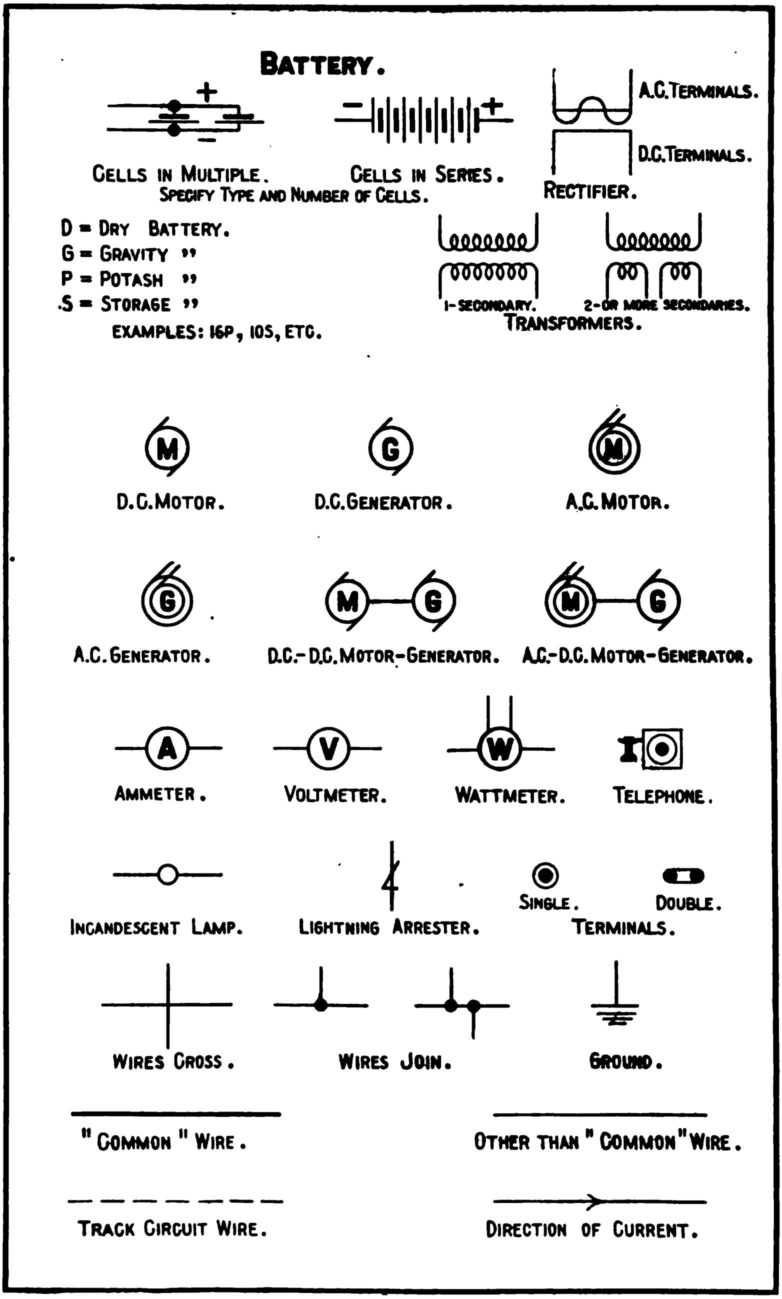

MANUAL TIME RELEASE.
(ELECTRIC)
MANUAL TIME RELEASE.
(ELECTRO-MECHAN'L.)
AUTOMATIC TIME RELEASE.
(ELECTRIC)
EMERGENCY RELEASE.
(ELECTRIC)
FLOOR PUSH.
LATCH CONTACT.
OPEN.
CLOSED.
TRACK INSTRUMENT CONTACT.
KNIFE SWITCHES.
RHEOSTAT.
SINGLE POLE.
DOUBLE POLE.
SINGLE THROW.
SINGLE POLE.
DOUBLE POLE.
DOUBLE THROW.
QUICK ACTING CIRCUIT CONTROLLERS MAY BE DISTINGUISHED BY THE LETTER "Q"
FIXED RESISTANCE.
VARIABLE RESISTANCE.
FUSE.
IMPEDANCE WITHOUT IRON CORE.
IMPEDANCE WITH IRON CORE
CONDENSER.

PLATE XII.


BATTERY.
CELLS IN MULTIPLE.
CELLS IN SERIES.
SPECIFY TYPE AND NUMBER OF CELLS.
A.C. TERMINALS.
D.C. TERMINALS.
RECTIFIER.
D = DRY BATTERY.
G = GRAVITY "
P = POTASH "
S = STORAGE "
EXAMPLES: 16P, 10S, ETC.
1-SECONDARY.
2-OR MORE SECONDARIES.
TRANSFORMERS.
M
G
D.C. MOTOR.
D.C. GENERATOR.
A.C. MOTOR.
A.C. GENERATOR.
D.C.-D.C. MOTOR-GENERATOR.
A.C.-D.C. MOTOR-GENERATOR.
A
V
W
AMMETER.
VOLTMETER.
WATTMETER.
TELEPHONE.
INCANDESCENT LAMP.
LIGHTNING ARRESTER.
SINGLE.
DOUBLE.
TERMINALS.
WIRES CROSS.
WIRES JOIN.
GROUND.
"COMMON" WIRE.
OTHER THAN "COMMON" WIRE.
TRACK CIRCUIT WIRE.
DIRECTION OF CURRENT.

Appendix A.

RULES GOVERNING THE CONSTRUCTION, MAINTENANCE AND OPERATION OF INTERLOCKING PLANTS.

The States of Wisconsin, Illinois, Indiana and Minnesota have adopted certain rules with reference to the construction, maintenance and operation of interlocking plants, and these rules have now also been adopted by the States of Missouri and Iowa. They are herewith presented to the Association as *information,* with the understanding that they have not been reviewed by Committee No. X. It is recommended that they be published in our literature, but not included in the Manual.

PRELIMINARY REQUIREMENTS.

Indications and Aspects.

SECTION 1. (a) As far as practicable, a uniform system of indications and aspects must be used for each operating division. When requested, every railroad company operating in this state shall submit plans to the Commission showing the system of indications and aspects in use, or which it proposes to use, for fixed signaling for each operating division.

(b) If changes are made by any railroad company in its system of signal indications and aspects on any operating division in this state subsequent to the filing of plans, it shall notify the Commission accordingly.

Plans to Be Submitted.

SECTION 2. (a) Prior to the construction, reconstruction or rehabilitation of any interlocking plant, there shall be filed with the Commission as a basis for approval, the following plans:

(b) A station map or other plat, drawn to scale, showing all tracks, bridges, buildings, water tanks, and other physical surroundings located on the right-of-way of each company.

(c) Profiles showing the grade of each railroad company's main tracks for a distance of not less than two (2) miles in each direction from the crossing or junction.

(d) A track plan in duplicate (and as many more as the roads desire approved) showing the location of all interlocking units, the tower and its general dimensions, and any other appurtenances necessary to show a complete layout of the proposed interlocking plant. When not expedient to locate accurately all physical characteristics by figures, they should be established by scaled distances within the interlocking limits hereinafter specified.

(e) When merely changes and additions are involved, no station maps or profiles need be filed with the track plans, except when requested by the Commission.

(f) All plans filed with the Commission under this and other sections must be of light-weight paper when in the form of blueprints.

Symbols.

SECTION 3. In the preparation of plans, the symbols approved by the Railway Signal Association shall be used to indicate switches, derails, signals, and other essential parts of the interlocking plant.

Limits of Interlocking Plants.

SECTION 4. The interlocking limits are defined by the home or dwarf signals situate on any specified track and located farthest from the point to be protected. Any appliances operated in conjunction with the interlocking plant, and situate beyond the limits herein designated, are considered as auxiliaries.

Approval of Plans.

SECTION 5. (a) When possible, the railway companies concerned should agree on the plans before submitting them to the Commission.

(b) If the preliminary plans are satisfactory, or if in the judgment of the Commission modifications are necessary, the plans will be approved accordingly. Of the plans so approved, one copy will be retained by the Commission, and the duplicate returned to the petitioning company.

(c) The approval herein described will stand for a period of one year. If the work is not commenced within that period, a new approval must be obtained.

Physical Changes, Reconstruction and Rehabilitation.

SECTION 6. No interlocking plant shall be reconstructed or rehabilitated, nor shall any change be made in the locking or in the location of any unit, until plans have first been submitted to and approved by the Commission.

Conditional Service.

SECTION 7. (a) Upon the completion of any work on interlocking plants, which involves changes in the locking, the units must be connected and adjusted, the plant placed in conditional service for not less than twenty-four (24) hours, and remain so until relieved by order of the Commission.

(b) When minor changes are made in locking, under plans previously approved by the Commission, it will not be necessary to place the plant in conditional service prior to the time it is ready for inspection; and in cases when permission is received from the Commission in advance, the plant may be placed in full operation, if the Commission is unable to inspect it within twenty-four (24) hours after it is ready for inspection.

(c) Conditional service is hereby interpreted to mean that all units and other apparatus involved be connected and operated from the interlocking machine in the tower. All trains shall come to a stop at the governing home or dwarf signal, regardless of its position, and that such signal shall not be operated to give a proceed indication until after the train has made the prescribed stop.

Petition for Inspection.

SECTION 8. (a) Prior to or accompanying the petition for inspection of completed interlocking plants, the following detailed plans will be required:

(b) A track plan similar to the one referred to in Section 2, showing all tracks and interlocking units as actually constructed, the terminal ends of each track to be numbered or lettered for use in connection with the manipulation sheet. A locking sheet and dog chart, showing the arrangement of locking in the machine as installed; wiring plans, showing in detail all circuits used in connection with the plant; a manipulation sheet, with or without track diagrams, as required by the Commission, showing in tabulated form the numbers of all levers necessary to be manipulated for any given route designated on the track plan.

(c) A suitable framed manipulation chart and track diagram shall be properly placed in the interlocking tower. The terminal ends of each track on this chart shall be numbered or lettered to correspond with the track plans above mentioned.

(d) The petition for inspection of any interlocking plant, when possible, shall give three (3) days' notice in advance of the time when the plant will be ready for inspection. Upon receipt of such notice, the Commission will endeavor to have the plant inspected within three (3) days after receiving such advice. If the Commission is not able to make the inspection within the time specified, it will authorize the railroad company in charge to place the plant in full operation, subject to future inspection.

(e) If, upon the inspection of any interlocking plant by the Commission, it is found to be installed in accordance with the approved plans, a temporary permit will be issued to the railroad company in charge, pending the issuance of formal permits.

REQUISITES OF INSTALLATION.

Type of Signals.

SECTION 9. (a) Except when approved by the Commission, all interlocking signals must be of the semaphore type. The apparatus connected with the operation of these signals must be so constructed that the failure of any part directly controlling the signal will cause it to display its least favorable indication.

(b) Semaphore arms must display indications to the right of the signal post, except where the physical conditions on a road require the display of signal indications to the left.

Location of Signals.

SECTION 10. (a) All fixed signals must be located either over or upon the right and next to the track over which train movements are governed, except on roads operating trains with the current of traffic to the left, or where physical conditions require placing the signals to the left of the track.

(b) Bracket post signals may be used on roads operating trains over two (2) or more tracks in the same direction, when such practice is uniform for any specified operation division, or where local conditions require their use.

Locking of Signals.

SECTION 11. The locking between the levers of the interlocking machine must be arranged so that a home or dwarf signal cannot be cleared for any given route unless all switches, derails, movable point frogs and other units in the route are in proper position and locked.

Home Signals.

SECTION 12. (a) When required by the Commission, all home signals must be equipped with not less than two arms. Unless operated by power, all home signals in mechanical plants must be pipe-connected, except when otherwise approved by the Commission.

(b) When used in connection with automatic train stopping devices, the home signal may be located immediately opposite the means for controlling the apparatus of the train stopping device.

(c) When used in connection with derails and other units, the home signal must be located as far in advance of such units as is necessary to secure full protection, but in no case shall it be less than five (5) ft. in advance of such units.

(d) When home signals are semi-automatic, or form a part of an automatic block signal system, calling-on-arms or some other means may be used for advancing trains.

(e) All high-speed signals located in an automatic block signal territory shall be semi-automatic and form a part of the block signal system.

Dwarf Signals.

SECTION 13. Dwarf signals indicate slow-speed movements and may be used to govern train movements on all tracks other than main tracks, except as hereinafter specified; on main tracks to govern train movements against current of traffic; and, when approved by the Commission, as intervening signals to facilitate switching movements. When used, they must be located and connected in the same manner as home signals.

Advance Signals.

SECTION 14. Advance signals may be used when necessary, and must be installed in the same manner as home signals.

Distant Signals.

SECTION 15. (a) On level and ascending grades, distant signals shall be located not less than two thousand five hundred (2,500) ft. in advance of their respective home signals. On descending grades, the minimum distance of two thousand five hundred (2,500) ft. shall be increased at the rate of one hundred (100) ft. for each one-tenth (1/10) of one per cent. of gradient.

(b) Where conditions justify, the location and character of distant signals or the method of operation may be varied or the signals be omitted, depending upon the conditions surrounding each particular case.

(c) Except as hereinafter provided, all high-speed tracks must be equipped with power-operated distant signals having electric locks or other suitable apparatus to prevent changing of the route until such signals have indicated their normal position.

(d) When required by the Commission, distant signals shall be so arranged as automatically to indicate stop when the track between the home and distant signals is occupied, or when any intervening switch is not in its normal position.

Switches.

SECTION 16. All switches, derails, movable point frogs and other units within the interlocking limits hereinbefore defined must be incorporated in the plant.

Derails on Steam Roads.

SECTION 17. (a) Main Tracks: On level grades, facing derails must be located not less than five hundred (500) ft. from a drawbridge or the fouling point of a crossing or junction. On descending grades, facing derails must be located to give practically the same measure of protection as for level grades, and the minimum distance of five hundred (500) ft. must be increased at the rate of ten (10) ft. for each one-tenth (1/10) of one per cent. gradient. On ascending grades, the minimum distance of five hundred (500) ft. may be reduced at the rate of ten (10) ft. for each one-tenth of one per cent. gradient; but in no case shall such derails be located less than four hundred (400) ft. from a drawbridge or the fouling point of a crossing or junction.

(b) Pocket Derails: Where such are used they shall be located so as to derail the first pair of wheels on the ties, at a point not less than fifty (50) ft. from the fouling point of a crossing or junction.

(c) Back-up Derails: These shall be placed not less than two hundred fifty (250) ft. from a drawbridge or the fouling point of a crossing or junction.

not less than two hundred (200) ft. from a drawbridge or from the fouling point of a crossing; and not less than fifty (50) ft. from the fouling point of a junction.

(e) The fouling point is where two trains moving toward a common center would come in contact.

(f) Where conditions justify, the location of derails may be varied or they may be omitted, when approved by the Commission.

Derails on Electric Roads.

SECTION 18. The location of derails on electric roads shall be determined in the same manner as for steam roads. In placing derails in the tracks of such roads, consideration will be given to speed and character of traffic.

Type of Derails.

SECTION 19. Derails must be of an approved pattern, suitable for the purposes intended and so placed with reference to curvature, bridges and other tracks as to secure a maximum of efficiency and safety.

Guard Rails.

SECTION 20. Where physical conditions require their use, guard rails shall be installed in connection with derails. When used, they shall be placed between the track rails, parallel to and not less than ten (10) in. distant in the clear therefrom, and must be of sufficient height, length and strength, and be properly secured to the track ties.

Automatic Train Control.

SECTION 21. Automatic train stopping devices which are a part of a system of automatic train control approved by the Commission, may be used in lieu of derails. In such devices, the means for automatically applying the train brakes shall be located a sufficient distance in advance of the fouling point as to insure a safe braking distance.

Locks.

SECTION 22. (a) In mechanical plants, all facing switches, split-point derails in main tracks and all slip switches and movable point frogs, must be locked with facing point locks. All other derails, switches and other units must be locked either with facing point locks or with switch and lock movements.

(b) In plants equipped with mechanical signals, all derails must be provided with bolt locks; also all switches, movable point frogs and other units, where conditions require them.

(c) In power plants, the arrangement must be such that the signals operating in connection with derails, facing point switches and other units, cannot be operated unless these units are in proper position.

Detector Bars.

SECTION 23. (a) Unless otherwise provided, all derails, switches, movable-point frogs and other units shall be equipped with detector bars of approved design, not less than fifty-three (53) ft. in length, or longer, if required.

(b) Except as hereinafter provided, all crossings shall be equipped with detector bars of suitable length, so interlocked as to insure a clear crossing before an opposing route can be set up or a proceed signal given.

(c) Crossing detector bars will not be required where electric locking is installed; nor at outlying crossings of simple character where no switching is performed, when the plant is equipped with time locks.

Time Locks.

SECTION 24. Unless equipped with electric locking, time locks must be installed to prevent the changing of high-speed routes, until after the home signal has displayed the stop indication a predetermined time.

Electric Locking.

SECTION 25. Electric locking may be provided in place of time locks and crossing bars. When used, the circuits must be arranged so as to prevent the changing of a route until the train has passed through the interlocking limits or through a predetermined part of the plant.

Detector Circuits.

SECTION 26. When a railway company is equipped with sufficient maintenance forces for properly maintaining electric detector circuits, such circuits may be used in place of mechanical detector bars.

Machines.

SECTION 27. (a) All mechanical interlocking machines shall be equipped with locking of the preliminary type.

(b) All power interlocking machines shall have the locking so arranged as to be effective before the operating conditions of any circuit directly controlling a unit can be changed. Suitable indicating and locking apparatus shall be provided to prevent the placing of a lever in complete normal or reverse position until the unit controlled has completed the intended operation, except that signals shall indicate the normal position only.

Locking of Levers.

SECTION 28. (a) The locking must be so arranged that conflicting routes cannot be given at any stage in the setting up of a route, nor a proceed indication given until all switches, derails, movable-point frogs, facing-point locks and other units in the route affected are in proper position.

(b) When a separate lever is used to operate distant signals, the locking between the home and distant signals shall be so arranged as to prevent the distant signals from giving the proceed indication until the home signals operating in connection with such distant signals are in the proceed position.

Locks and Seals.

SECTION 29. (a) All interlocking machines must, when practicable, be provided with means for locking or sealing the mechanical locking and indication apparatus in such a manner as to prevent access to any except authorized employes.

(b) All power interlocking cabinets, time locks, time releases, emergency switches, indicator and relay cases must be provided with suitable covers and fastenings and be properly sealed or locked, and must not be opened by any but authorized employes.

Cross Protection.

SECTION 30. (a) As far as practicable, cross protection apparatus must be provided in connection with electric interlocking plants, to prevent the operation of any unit by cross or grounds.

(b) Low voltage circuits, as far as practicable, must be designed to prevent the operation of apparatus by cross or grounds.

Annunciators.

SECTION 31. When operating conditions require annunciators, they shall be installed.

Signal Towers.

SECTION 32. (a) Signal towers shall be so placed and be of such height and size as to best serve the purpose for which they are intended.

(b) The use of interlocking towers for purposes other than interlocking, dispatching and block work is undesirable.

having access to interlocking apparatus, and interfering with the duties of the operator or towerman.

Tower Lights.

SECTION 33. The tower lights must be screened off so that they cannot be mistaken for signals exhibited to control train movements.

Material and Workmanship.

SECTION 34. Material and workmanship must be first-class throughout. When complete, the interlocking plant must be in every way suitable and sufficient for the purposes intended.

MAINTENANCE AND OPERATION.

Maintenance and Operation.

SECTION 35. (a) Interlocking plants must at all times be properly maintained and efficiently operated. Any rules or regulations that the railway companies may have adopted for the guidance of employes in operating and maintaining interlocking plants must be appropriately framed and conveniently placed in interlocking towers.

(b) When an interlocking plant is taken out of service the Commission must be notified immediately. Under such circumstances train movements must not be governed by interlocking signals, but by the usual precautions prescribed by statute governing train movements over and across railroad grade crossings, junctions and drawbridges.

Interlocking Reports.

SECTION 36. Reports for each interlocking plant shall be filed with the Commission by each railroad company concerned, which reports must be filed in manner and form prescribed by the Commission.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

C. H. Spencer, *Chairman;*
W. G. Arn,
H. Baldwin,
G. H. Burgess,
A. E. Clift,
H. T. Douglas, Jr.,
A. C. Everham,
R. Ferriday,
G. H. Herrold,
G. P. Johnson,
D. B. Johnston,
H. A. Lane,

E. B. Temple, *Vice-Chairman;*
L. J. McIntyre,
B. H. Mann,
A. Montzheimer,
H. J. Pfeifer,
S. S. Roberts,
W. L. Seddon,
E. E. R. Tratman,
E. P. Weatherly,
W. L. Webb,
C. C. Wentworth,
J. G. Wishart,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Yards and Terminals submits herewith its fourteenth annual report.

The Board of Direction has assigned the following subjects to your Committee:

(1) Report on typical situation plans of passenger stations, of both through and stub types, with critical analysis of working capacity, and include a review of the different methods of estimating their capacity.

(2) Report on developments in the handling of freight by mechanical means.

(3) Report on developments in the design and operation of hump yards.

(4) Report on track scales.

In addition to various meetings of sub-committees, to whom the different subjects have been assigned, two meetings of the entire Committee were held, the first in Buffalo, June 6 and 7, at which were present: Hadley Baldwin, A. E. Clift, A. Montzheimer, J. G. Wishart, C. C. Wentworth, G. H. Herrold, S. S. Roberts, R. Ferriday, D. B. Johnston and C. H. Spencer.

The second meeting was held at Atlantic City, September 26 and 27, at which were present: Hadley Baldwin, G. H. Burgess, D. B. Johnston, H. A. Lane, R. Ferriday, C. C. Wentworth, S. S. Roberts and C. H. Spencer.

Letters were also received from E. B. Temple, A. E. Clift, H. T. Douglas, Jr., A. C. Everham, D. B. Johnston, B. H. Mann, W. L. Seddon, E. E. R. Tratman, E. P. Weatherly and H. J. Pfeifer.

TYPICAL SITUATION PLANS OF PASSENGER STATIONS.

The work on this subject has been industriously prosecuted by the members of the sub-committee handling the same. Arrangements are being completed for putting in use the diagrams submitted by the Committee in its last report in some of our large terminals. This has not been carried to the extent which would allow a report to be made at this time. The Committee, therefore, desires that the subject be carried over until its next report. The Committee also calls attention to an article on "The Traffic Capacity of Terminus Stations for Urban and Suburban Traffic," by G. Brecht, Berlin, published in Elektrische Kraftbetrieber und Bahnen, and reprinted in Bulletin of the International Railway Congress Association, English Edition, Volume XXVII, November, 1913.

DEVELOPMENTS IN THE HANDLING OF FREIGHT BY MECHANICAL MEANS.

The subject with which the Committee has to deal may be divided into three classes: (1) the mechanical handling of freight at freight houses; (2) the mechanical handling of freight in general, at warehouses, piers, etc.; (3) the mechanical handling of railway baggage, mail and express matter. These three divisions of the subject are covered in this report.

MECHANICAL HANDLING OF FREIGHT AT FREIGHT HOUSES.

The difficulty in the application of mechanical conveying devices to the handling of freight in freight houses is not in devising such appliances, but in adapting them to conditions of handling (1) where the sizes and weights of packages are of infinite variety, and (2) where there are numerous points for receiving and delivering the packages.

Where there is a fixed point for loading and discharge, as in a warehouse or an industrial plant, it is simply a question of adopting one of several forms of conveyors. But it is a very different problem to handle freight which is delivered at a dozen or a score of team doorways (or an equal number of points along a platform), and which must be distributed among a still larger number of cars. This problem has not yet been solved, and the nearest approach to its solution so far appears to be the introduction of small motor trucks as a substitute for hand trucks, thus retaining the flexibility and independence of the trucking system, while increasing the capacity and speed of movement.

The Committee has but little specific information to report on this subject. In its report for 1913 it described in detail the telfer system as used for the double-deck freight station of the Missouri, Kansas & Texas Railway at St. Louis, but the use of that system has now been abandoned. In reply to an inquiry as to the reason for this action, Mr. S. B. Fisher

(now Chairman of the Valuation Committee of that railway) writes as follows:

"Our Company has abandoned the method of handling freight by telfers, as our freight was of such a miscellaneous character and with such unhandy packages that we could not handle it economically with this system. I think, however, the principal difficulty is that our men were not educated enough for the handling of this freight, and that we were too far in advance of the times. It is true with the outbound freight we had the principal difficulty. We found a great deal of breakage, and freight shipped to wrong destinations under this system."

Texas City Transportation Company: This plant is primarily for handling heavy freight, principally steel products from vessel to car and vice versa, and consists of a main longitudinal conveyor at right angles to the wharf with portable branch conveyors at right angles to the main conveyor, the latter of which can be placed at any point along the main conveyor, permitting storing at any point in the storage room, and in the outbound house loading directly into the cars which are placed on tracks at each side of the outbound house and parallel to the main conveyor.

With this plant the only manual labor is placing the freight on the conveyor in the hold of the vessel, diverting at each junction the freight for the branch conveyor at that point and then stacking the freight in the house or in the car.

By reversing the movement on conveyors, cotton and cotton seed products and other freight are conveyed directly from cars or storage room to the hold of the vessel or from car to the storage room.

With this system the cost of handling freight from vessel to cars or warehouse is a minimum of about eight cents per ton for steel products and a string of cars has been loaded in an average of ten minutes per car.

A plan of the whole terminal, and of the storage room and outbound house, are given, together with some views.

It is unnecessary to change the berth of a vessel at any dock and it, therefore, makes less dock space necessary than with the ordinary system of a narrow dock parallel to the water front, and gives a minimum of port delay to a vessel. Land back for half of mile from water front can be used to as good advantage as frontage, and as such land is cheaper, the initial expense is reduced, it being necessary to have only frontage enough to berth the vessels docking at the wharf at any one time.

The main artery of the conveying apparatus consists of a series of individual slat conveyors (see Fig. 1) of such length that each is economically run by its own motor, and they are so coupled together as to virtually form one continuous conveyor.

At the junction of branch conveyors (see Fig. 2) when delivering to the branch, it is necessary to station a man at each junction where freight is being diverted. However, when freight is being delivered from the branches to the main conveyor, it is unnecessary, for many small pack-

FIG. 1—MAIN CONVEYOR, TEXAS CITY TRANSPORTATION COMPANY.

ages, to have a man at the junction to divert the packages. The almost unbelievable extent to which this transfer can be made to the main conveyor from branches at right angles without manual help is illustrated by the fact that a Hanak slat conveyor in the Magnolia Brewery at Hudson so handles bottled beer, the bottles standing upright, in conveying it from bottling machine to the packers (see Fig. 3).

Magnolia Compress, Harrisburg, Texas: This plant, also, designed by Edward Hanak, used exclusively for handling cotton, is equipped with roller belt conveyors, and handles cotton from compress or any point in receiving sheds to the cars or any floor of a four-story storage warehouse. The conveyor to storage warehouse passes over the railroad track, is so adjustable that by reversing the conveyors cotton from the storage warehouse can be delivered direct to cars. This system has proven economical and very satisfactory, and while it would be difficult to adjust any existing plant to such an apparatus, it seems ideal for a new project. Plan indicating installation and cuts illustrating use are included in the report (see Figs. 9, 10, 11, 12).

FIG. 3—BOTTLE CONVEYOR, RIGHT ANGLE.

IMPROVEMENTS IN HAND TRUCKING AT FREIGHT HOUSES.

In many cases it may be practicable to materially improve the hand trucking system at freight houses, and two instances of such improvement may be mentioned.

The Illinois Central Railroad has used at its Chicago local freight house a method of handling L. C. L. freight which is known as the multiple truck system. There are 5 to 15 trucks to each trucker, and when a man brings his truck he does not wait for it to be loaded or unloaded (as is ordinarily done), but takes another truck and handles another load.

FIG. 4—ELEVATOR, TEXAS CITY TRANSPORTATION COMPANY.

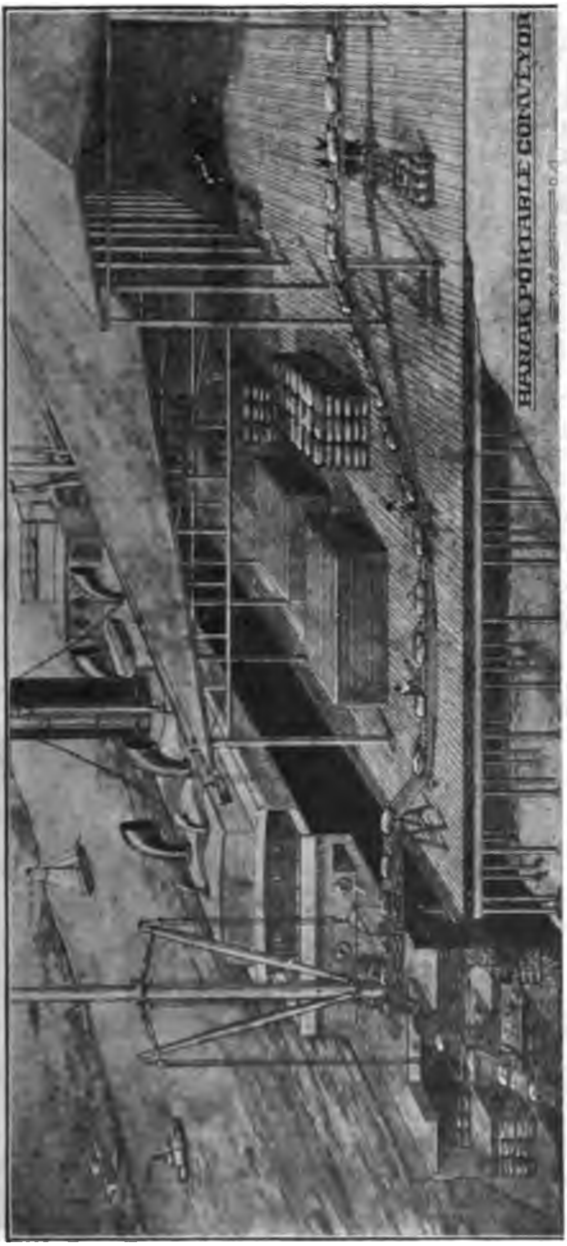


Fig. 5.

FIG. 6—MAIN CONVEYOR IN SHEDS, MAGNOLIA COTTON COMPRESS, HOUSTON, TEXAS.

FIG. 7—PORTABLE CONVEYOR IN SHEDS, MAGNOLIA COTTON COMPRESS, HOUSTON, TEXAS.

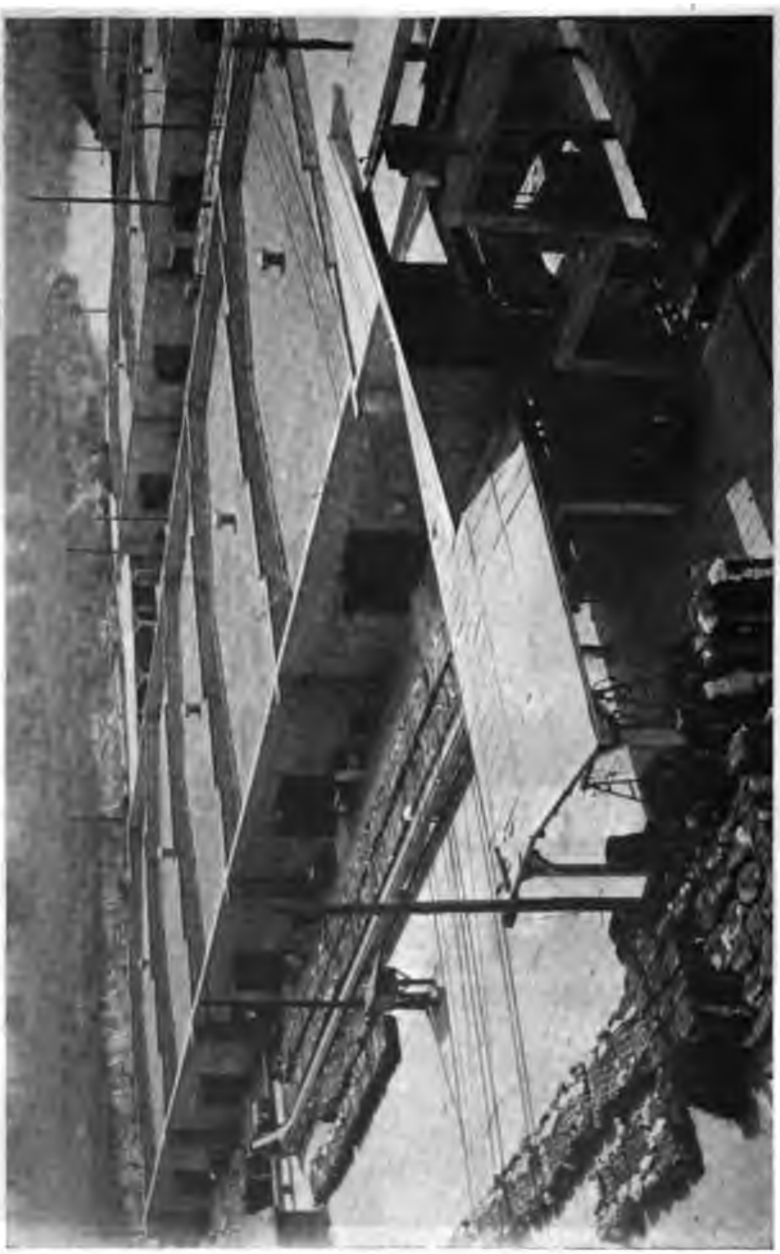


Fig. 8—Cross Conveyor From Main Conveyor to Storage Warehouse, Magnolia Cotton Compress, Houston, Texas.

FIG. 9—STACKER, MAGNOLIA COTTON COMPRESS, HOUSTON, TEXAS.

This eliminates much of the empty truck movement and the enforced idleness of the truckers, which prevails under the ordinary system. It reduces the cost of floor movement about 30 per cent. Fifty per cent. of the saving is being distributed among the freight handlers in the form of increased pay. In describing this system at a meeting of the Traffic Club of Chicago, Mr. Barron suggested that in the absence of mechanical carriers or moving platforms in the city terminals the efficiency of freight handling could be greatly increased by the establishment of large outer sorting platforms or warehouses where outbound package freight could be assembled and consolidated, and where the floor movement could be performed by mechanical devices.

In replacing the telferage system with hand trucking at the St. Louis freight station of the Missouri, Kansas & Texas Railway mentioned above, steps were taken to reduce the time lost by truckage. The station being double-decked (with the team platforms above, the car platforms below), trucks have to be handled by elevators. As described, there are two separate groups of truckers, one for each floor. For outbound freight a trucker on the upper floor will take a loaded truck and run it into the designated elevator, taking off an empty truck and going back for another load. A trucker on the lower floor will take the loaded truck and wheel it to the car, where he will leave it and take an empty truck back to the elevator.

CONVEYORS FOR HANDLING MAIL AND BAGGAGE.

Carrying mail bags from trains to a post-office sub-station by means of belt conveyors is an interesting feature of the new Chicago terminal of the Chicago & Northwestern Railway. There are six belts running in covered troughs between the pairs of tracks, and a little below the rail level. When a train arrives, sections of the cover of the trough are removed, opposite the mail-car doors, and the bags are thrown down upon the traveling belt. Similar belt conveyors have been installed for handling the mail in the postoffice at the above terminal. Spiral chutes for lowering mail bags and hand baggage are in use at the New York Terminal Stations of the New York Central Lines and the Pennsylvania Railroad.

Practically the only method of handling train baggage by power at large stations is by the use of electric motor trucks. At several steamship piers portable conveyors (of the traveling platform type) are used to deliver baggage to and from the vessels, while fixed conveyors of a similar type handle it between the upper and lower floors of the piers.

In regard to trucking at passenger stations, the operation of trucks on passenger platforms is always more or less of a nuisance. In several cases where baggage is handled beneath the train floor, the trucks with inbound baggage still have to run from the baggage cars along the plat-

WAREHOUSE AND PORTABLE CONVEYOR.

TEXAS CITY TRANSPORTATION CO.,

TEXAS CITY, TEXAS.

FIG. 10—CONVEYORS AND REVOLVING CONE FOR HANDLING PACKAGES, AMERICAN EXPRESS COMPANY, NEW YORK.

FIG. 11.

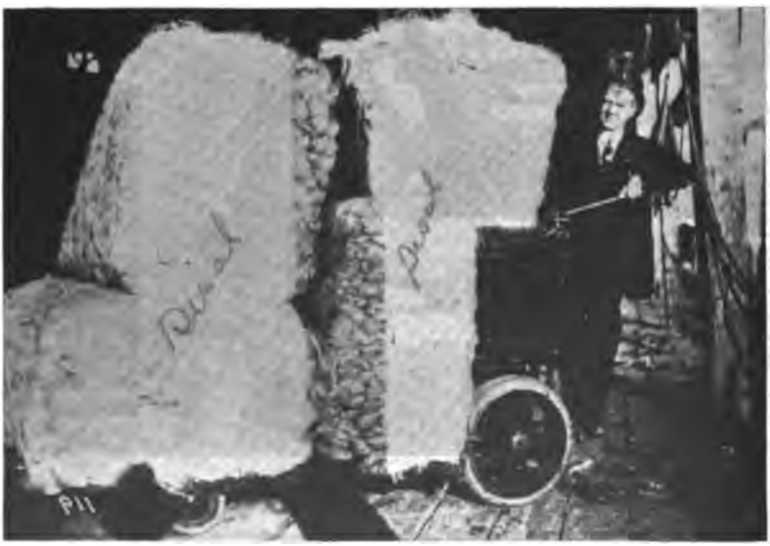


FIG. 12.

CONVEYORS FOR HANDLING EXPRESS AND PARCELS.

Conveyors and escalators (or inclined elevating conveyors) have been used at several express offices and stations, and a telfer system is referred to later in connection with foreign conveyor practice.

At the American Express Company's station at West Thirty-third Street and Tenth Avenue, New York, there is an interesting conveyor system. The loaded wagons coming to this station are backed against an unloading platform, which is served by a 40-inch belt conveyor 555 feet long, placed 7 feet above the platform and 3 feet back from its edge. The smaller packages are thrown upon this by the wagon crews as they unload their vehicles. The belt is driven by a 7½ H.P. direct-current motor and runs at a speed of ninety feet per minute.

At the end of this conveyor the packages slide down a short chute to another 40-inch belt conveyor, which is 66 feet long and inclined at an angle of twenty degrees so as to deliver the packages to the upper floor. This conveyor is driven from the other by means of sprocket chains. The packages are discharged upon the apex of a revolving cone or turntable as shown in Fig. 10. This is 22 feet in diameter. As the packages slide down the cone to the base they are picked off and thrown into bins by men stationed around the turntable, each man taking off those destined to certain offices. The turntable makes about one revolution per minute and is driven by gearing from a 1 H.P. motor. From these bins the packages are taken by men who weigh them and assess the proper charges. Then the packages are placed on an inclined table, at the base of which is a shelf where the waybill is made by men seated at this shelf. The packages are then placed on another table, from which they are placed in cases (called "trunks"), one or more cases being used for every large office and other cases being addressed to a messenger on a train, from which he will distribute the packages to the offices through which his train passes. After being locked and sealed, the cases are trucked to an escalator, or inclined platform conveyor, and sent to the main platform for loading into the proper cars. This escalator is 48 inches wide and 35 feet long, operated by a 5 H.P. motor. It will run in either direction, and in the morning it is used for taking empty cases from the train platform to the package room. The revolving cone is a new feature which has been found entirely satisfactory. It eliminates the possibility of congestion and its use shows a decided saving in labor.

Similar equipment is used at the express offices of the Wells-Fargo Company at Jersey City and at the express stations of the United States Express Company in the terminal stations of the Erie Railroad at Jersey City and the Delaware, Lackawanna & Western Railroad at Hoboken, N. J. At this last named station the loaded express wagons are backed up to the receiving doors and the heavy trunks, etc., are put on the main floor to be handled by trucks, while the lighter packages (up to about 30 lbs.) are thrown upon a wide belt conveyor above and at a short distance back from the doors. A low side board or guard along the near side of the

belt and a high guard at the back prevent packages from being thrown on the edge or thrown over the belt. There are two of these belts, each 300 feet long, running from the opposite ends of the express platform towards the middle. Each discharges at the end upon an inclined conveyor 44 feet long, which extends into the second floor and delivers the packages upon a picking belt, from which they are taken by boys who pass them down chutes to the billing clerks, each clerk taking those for certain routes. If the packages come so fast that the boys cannot handle them, those that are not taken go on to the end of the belt and are delivered by chutes to a parallel return belt and again discharged upon the picking belt, the parcels circulating in this way until taken off.

CONVEYORS AT PIERS AND DOCKS.

Motor trucks and different kinds of conveyors are used for handling freight and cargo at steamship piers, but mainly in connection with coastwise shipping. Some conveyors handle the packages of freight, others handle the trucks, as noted below in reference to different kinds of conveyors. A portable cargo-handling conveyor consists of a conveyor belt on a truss frame which is hinged to a steel tower traveling on a track along the edge of the pier or quay. A motor drives the conveyor and propels the tower. The end of the truss is supported by cables which pass over the top of the tower and down to winding drums, so that the inclination of the conveyor can be varied to meet the level of the deck of the ship or barge.

At American ports, the handling of cargo is done mainly by the ship's winches and booms and by hand trucks. At the extensive pier and warehouse plant of the Bush Terminal Company, Brooklyn, N. Y., the company leases its piers to steamship lines, and these lines handle their own cargoes. They do not use mechanical means except such as the ships themselves provide. A new pier for the American-Hawaiian Line will have a double-deck shed, and the steamship line considered seriously the matter of using equipment other than booms on the ships. It decided finally that it would install only booms on the side of the pier shed, about thirty feet apart. The second deck will be used only for incoming cargo. In getting this cargo down to the first deck it is expected to use straight chutes, spiral chutes, and "lowerators."

In its own work the terminal company loads cars mostly by hand, but sometimes with small movable cranes mounted on storage-battery motor trucks. The goods are moved between cars, docks and warehouses partly by mule trucks and partly by battery trucks with trailers. The goods are put into and taken out of the warehouses by electric hoists placed at intervals along the bulkhead, and which are so arranged that the drum can be hooked up to any one of several different hoists. For distributing

Some examples of freight handling installations at piers are given below:

Merchants' and Miners' Transportation Company: This company is using a portable gravity conveyor system at its steamship pier at Boston. The conveyor consists of ball-bearing rollers carried in side frames which are mounted on legs, giving an average grade of 4 per cent. The sections are about six feet long and their frames hook together. As used on the pier, a main run of the conveyor extends from the storage side of the shed to the water side, and branches (with connecting curves) are laid down the gangways and across the ship's deck to the hatches. Four hatches can be served at once.

The company states that this carrier has been found economical where used for one kind of freight and where the grade is uniform, but at Boston there is a tidal range of 9 to 12 feet, and the character of freight is miscellaneous, consisting of sacks, boxes, bales, barrels, etc.

It has been in use about a year with fair results. The greatest length of travel is 150 feet and the speed of movement about 300 feet per minute, while the heaviest packages handled average 400 lbs. It is considered that it would be superior to hand trucking if the packages were uniform and would then reduce the number of men by some 20 per cent. Its disadvantages are in handling the variety of packages and in the congestion at the ship's ports.

Boston & Maine Railroad: This road mechanically handles freight at pier 45, Boston, Mass., where there is a Reno escalator which consists of a wooden frame 46 feet long and 12 feet wide, extreme grade 21 degrees, with two Reno chain escalators, driven by separate 10 H.P. motors, which are reversible so that chain can go in either direction. The chain engages the axle of two-wheel trucks, pulling up and letting down load. The chains have two speeds, 150 feet per minute maximum, four to six trucks on each. Capacity 5 tons concentrated load. The frame is adjusted to suit the tide with a hand hoist.

Delaware, Lackawanna & Western Railroad: This road has at Hoboken, N. J., a new pier 500 by 80 feet, where eastbound freight is unloaded from cars and loaded onto barges for transfer to steamship piers. It has a double-deck steel frame superstructure with concrete walls, floors and roof. For handling freight between the main and upper floors, there are three 5-ton hydraulic platform elevators (9x10 feet) and five electrically operated barrel and sack elevators (with arms holding the packages). For descending freight there are also gravity chutes for packages and for barrels, movable sections carrying the freight from the bottom of the fixed chute to the desired points on the floor.

New York Dock Company: This company has piers and warehouses at Brooklyn, New York, and uses both motor trucks and conveyors for handling miscellaneous freight between the warehouses and the bulkhead line, but these facilities extend along the piers. A six-story warehouse is served by a telfer system which extends through the second floor and

over a bridge to a railway freight house. From the front of the warehouse, the runway extends along a bridge which crosses the dock front by a 76-foot span, the other end of the bridge being carried by a tower on the bulkhead wall. A hinged apron 30 feet long can be lowered so as to extend the runway over the deck of a barge or lighter. The runway is a 15-inch I-beam and carries electric hoisting trolleys of 5,000 lbs. capacity. These trolleys handle special freight trucks having platforms 3½ by 8½ feet, mounted on two casters at one end and two 10-inch ball-bearing wheels at the other end.

Canadian Pacific Railway: This railway has at Fort William, Ont., a freight pier which is used largely for shipping flour, and is equipped with electrically-operated belt conveyors for handling the sacks. Along the rear or track side, and just beneath the upper floor is a 26-inch conveyor belt extending the full length of the building, while five transverse belts (at a slightly lower level) extend across the building to fixed chutes. Portable chutes attached to these carry the sacks to the hatches of the vessel. Over the main belt, at each of the transverse belts, is a diverting device which consists of a board placed at 45 degrees across the belt, so that when lowered it throws the sacks off upon the transverse belt. By the operation of these boards, the sacks can be sorted while moving, so as to deliver a certain brand at each hatch if desired.

FREIGHT HANDLING AT WAREHOUSES.

At many large mail-order houses mechanical handling and conveying of packages is used extensively.

Mr. J. C. Madison, Traffic Manager for Montgomery Ward & Co., Chicago, informs us that in its various houses this firm is using as many mechanical appliances as may be economically adopted in conducting the business. The elevators are used as far as possible for ascending merchandise. For descending merchandise, spiral chutes are used; and belt conveyors for conveying merchandise from different divisions to the spiral chutes. At the foot of the spiral is a broad belt conveyor running the length of the building which carries the merchandise to the different packing sections, and it is run from this horizontal belt conveyor on gravity conveyors to different parts of the floors where it is wanted. Vertical endless-chain conveyors are used for taking up and down merchandise which is conveyed in baskets, and which cannot be safely sent down spiral conveyors.

There are inclined conveyors from the river-level floor to the shipping floors and they are adapted to handle heavy merchandise of all kinds. Supplementary elevators run from the box shop to the packing floors, and the pneumatic tube system is used throughout the building for the transfer of correspondence, mail, etc.

One or two portable elevators are used for stacking or double-decking

TYPES OF CONVEYORS FOR FREIGHT HANDLING.

Telferage: This system of handling goods by motor trolley hoists running on overhead runways is being used extensively. An electrically operated telfer system has been installed at the Hood Rubber Company plant, East Watertown, Mass., for handling loads of 250 to 5,000 lbs. It serves five buildings and crosses a railway line, which separates a group of buildings, and in this way it eliminates a former detour to a grade crossing. The runway is a single 12-in. I-beam, carried on brackets along the outside of the walls of the buildings and by steel bridges between the buildings. On this runs the motor trolley with a 2½-ton hoist. There are grades of 2½ and 4 per cent. on the line. It is stated that two years' service with one trolley, which was not sufficient to entirely eliminate handling by teams and trucks around the plant, reduced the operating cost of handling the material around the plant by 67 per cent., as compared with the former exclusive use of teams and trucks.

The four-story warehouse of the wholesale grocery firm of M. A. Newmark & Company at Los Angeles, Cal., handling some 200 tons daily, has a telfer system on each floor, with two spiral chutes and four elevators. Packages in the cars are loaded into small trucks, which are then pushed out on the platform to be picked up by the telfer carriers. Loads are carried from cars to the storage in less than two-thirds the time, and with less men than required by the former system.

Belt and Platform Conveyors: These are of numerous designs adapted to various purposes, and are used very extensively for both horizontal and inclined movements, for short and long distances. In some cases they extend across bridges from a warehouse to a pier or dock front, and by a hinged extension at the end the package can be delivered or loaded at the ship's hatch. One form of portable cargo conveyor has its belt frame carried on a truss attached to a tower or frame which travels along the dock wall. The attachment is hinged and the outer end of the bridge supported by cables from the tower, so that the inclination can be varied to suit the level of the ship or barge. Belt conveyors have been applied to the handling of mail sacks, light baggage and express matter at postoffices and railway stations, and for handling baggage at steamship piers.

Gravity Conveyors: These consist of rollers carried in side frame; mounted on legs, and for portable use the conveyor is made in sections (straight and curved) about six or eight feet long. The Matthews conveyor uses ball-bearing steel rollers, and gives a grade of about 4 per cent. It will handle loads of 5 to 300 lbs. For portable use, the legs of each section may be fitted with castors. These can be used only for a downgrade movement, but for long runs in factories, warehouses and industrial plants an automatic motor-driven inclined or vertical elevator raises the packages to the top of the gravity run. Spiral conveyors are made in the same way, and where packages of various kinds are used they have the advantage that all packages move at approximately the same speed,

while in spiral sliding chutes the speed varies with the weight and a heavy package may overtake and crush or damage a lighter package. These conveyors are used extensively in industrial work, and several railways are using short runs of them for special purposes such as handling shingles, brick, etc.

Gravity Chutes: Straight and spiral inclined chutes are used extensively in stores, warehouses, etc., also, at some railway stations for lowering mail sacks and light baggage from upper to lower floors. Open chutes or troughs are used for the larger and heavier class of packages, but for lighter packages the chute is a steel spiral inclosed in a steel cylinder, with loading doors or discharging chutes at the different floors. The openings are equipped with automatic fire doors.

Truck Conveyors: To facilitate the movement of hand trucks on inclines, there are different makes of traveling chains and platforms, the chains having arms or lugs to engage the trucks. These are used in pier sheds, warehouses, etc., but more extensively at steamship piers, on the inclined gangways from the floor to the level of the ship's lower-deck side ports. The trucker keeps hold of his truck in the usual way, and in some cases the chain forms part of an endless traveling platform on which the men stand, but usually the men walk beside the chain. This method is a great saving of time and labor, especially where the incline is steep, as in reaching the deck level at low tide. A modified application of this is a traveling chain laid along the floor of a pier or warehouse, forming two straight runs with loop ends. Trucks may be wheeled to the conveyor at any point. Empty trucks can be returned on the side of the run.

Motor Trucks: The use of motor trucks of about 1-ton capacity for handling freight and baggage is on the increase, and such trucks seem to be the most practicable method so far devised to increase the facility and economy of ordinary freight-house work. A special form of motor truck has been introduced, equipped with an electrically operated crane capable of handling loads up to one ton. This could load cotton bales, etc., upon its own platform, carry the bales to a wagon, and load them on the wagon; it can also handle such loads to and from other trucks.

Illinois Central Railroad: At Stuyvesant Docks, New Orleans, they have in use four Elwell-Parker electric trucks of the following sizes:

Capacity	4,000 lbs.
Speed, empty	7 to 8 M.P.H.
Speed, loaded	5 to 6 M.P.H.
Weight with Edison Battery	1,750 lbs.
Edison Battery	21 cells A-6
Turning radius of outside wheels	7 feet
Length of rear platform	4 ft. 9 in.
Width over body, front end	3 ft. 6 in.
Width over body, rear end	3 ft.
Width over stake pockets	3 ft. 8 in.
Height over body, front end	3 ft. 9 in.
Height over rear platform	10¾ in.

COMPARISON OF OPERATION COST

HAND TRUCK WITH ELWELL ELECTRIC TRUCK

Stuyvesant Docks, New Orleans

Day and Date	No. Machines Used	Hours in Use	Mileage	Commodity	Tonnage	Aver. Length of Haul, in Feet	Weight per Load in Pounds	Hours Loading and Unloading	Hours Running	No. Operators Required Elec. Truck	Cost of Labor Operating Elec. Truck	Cost of Current	Cost of Repairs—Elec. Truck	Interest and Depreciation	Total Cost—Elec. Trucks	Aver. Cost per Ton	Estimated No. Men to Run Hand Trucks	Cost Men Operating Hand Trucks	Cost of Repairs—Hand Trucks	Interest Depreciation	Total Cost Operating Hand Trucks	Average Cost per Ton Hand Trucks
1913																						
January...	3	265	220.5	Various	4196	529	2880	159.89	60.67	11	557.46	33.00	15.80	42.51	648.77	.1546	14	709.12	9.93	1.81	720.86	.1717
February.	3	248½	203.7	Various	5743	589	3799	182.18	66.57	18	892.54	27.71	50.20	45.03	1015.48	.1768	18	1136.00	7.97	1.45	1145.42	.1994
March....	3	158½	183	Various	2336	840	2135	100.65	57.85	11	321.98	22.75	43.10	24.26	412.09	.1764	14	423.60	6.63	1.20	431.43	.1846
April.....	4	161¼	287.4	Various	3751	861	1980	97.06	61.69	11	333.27	32.91	38.70	43.45	448.69	.1196	13	494.73	9.17	1.66	505.56	.1347
May......	3	123¾	188.3	Various	2509	697	2476	67.34	56.41	12	323.80	43.32	65.81	30.64	463.57	.1847	15	453.53	7.01	1.27	461.81	.1840
June......	3	125	177.2	Various	3418	555	2641	184.86	50.14	12	322.93	37.87	22.12	29.37	412.29	.1206	18	609.02	9.41	1.50	619.93	.1813
Total...	......	1092¼	1260.1	....	21953	......	......	......	......	......	......	......	......	......	3400.90	......	....	....	....	....	3885.01	......

Total Cost per Ton—
Electric Truck...............$ .1549
Hand Truck................. .1770
Decrease................... .0221
Increase.........................
Net Saving................. 484.11
Loss.............................

Each of these trucks frequently handle one and two trailers. Fig. 11 shows one of these trucks pulling mahogany logs from the ship side of the docks to the railroad side for loading on cars. Fig. 12 shows another handling a load of sisal. These trucks are also used in re-handling tobacco from warehouse to wharf, in which event the trucks keep six men busy loading, two unloading and one operator for each truck. In transporting cotton the trucks keep four men busy unloading, one operator for each truck. The performance of these trucks for six months ending June 30, 1913, as compared with former hand trucks is shown in the accompanying table.

MECHANICAL HANDLING ON ENGLISH RAILWAYS.

An inquiry as to the use of appliances for the mechanical handling of freight on English railways indicates that with few exceptions the only appliances of this kind are elevators and cranes at freight and passenger stations. At docks and quays cranes are employed to handle baggage to and from steamers. At coal shipping ports, special hoists and electric and hydraulic cranes are used; also car-dumping machines (for the small cars used on English railways.) A class of freight-house crane used in England is an overhead traveling crane, with a revolving trolley hoist fitted with a horizontal boom.

Lancashire & Yorkshire Railway: From Mr. John A. F. Aspinall, General Manager, we have some more detailed information as to appliances used for various purposes on this road, and these are noted below:

Handling Baggage at Passenger Stations: At the Victoria Station, Manchester, there is an overhead telfer system for handling parcels and light baggage between the parcel office and the train platform. The runway is composed of a pair of flat bars attached to the legs of horseshoe yokes suspended from the trainshed and roof trusses, and on this runs the electric traveling hoist or trolley, which has four grooved wheels. The hoisting chains carry slings for the attachment of a basket 5½x3x3 ft., in which the packages are carried. The total weight, including basket (empty) and operator, is nearly 1,300 lbs., and the hoisting capacity is 1,100 lbs. The runway forms an irregular loop, crossing all the platforms and extending to the baggage and parcel room. This system is the invention of Mr. Aspinall.

The only other baggage handling appliances are electric and hydraulic hoists to reach the streets (above or below track level) or subways connecting the platforms.

Handling Baggage at Docks or Steamship Piers: At this Company's steamship piers baggage is taken by hand to or from the trains at the side of the quay and lifted by means of an electric and hydraulic crane to the vessels. At Belfast, where no cranes are available on the quay, and where there is a constantly varying level between the ship and the

Handling Freight at Freight Stations and Yards: On the Lancashire & Yorkshire Railway system the large freight stations and yards are well equipped with various appliances. In Lancashire, heavy cotton traffic (which is dealt with in flat cars of 8 to 10 tons capacity), is handled by means of steam and electric overhead traveling cranes. A variation of this is the use of steam or electrically-driven gantry cranes. Light goods are handled usually by electric, hydraulic or manual cranes of 3,300 lbs. capacity fixed on a stage or platform. The company has been going in very largely for sheds fitted with fast overhead electrically-driven cranes of 1,680 to 3,360 lbs. capacity. The bridge is composed of a pair of parallel boom horizontal trusses, with the hoisting trolley traveling on the lower booms. These are very suitable for bales of cotton and light machinery and also paper and special traffic, as by this means a large volume of traffic can be handled at a very low rate per ton.

Special cranes include an electric cantilever gantry crane of 10 tons capacity, with truss 180 ft. long on a central tower for handling timber at North Mersey, Liverpool; also electric walking cranes in a wool warehouse at the Bradford freight yard. This wool warehouse is the largest and most completely equipped in England. The mast of the crane is mounted on a frame with wheels traveling on a single rail in the floor while the head rides in guides on the girders; it carries a revolving boom.

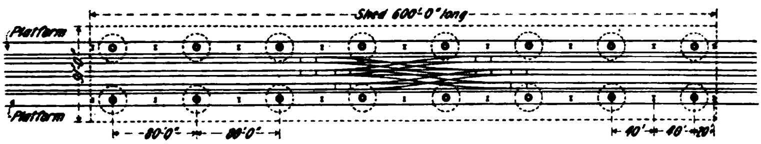


FIG. 13.

Goods or Cargo at Docks: At the docks and piers of this railway company two systems are in force: (1) serving the ships' hatches by means of crane (electric, steam or hydraulic) on the pier; (2) loading or discharging by means of the vessels' own steam winches.

Coal or Minerals at Shipping Docks: This railway ships large quantities of coal and salt at its two terminal ports. This is done by means of 25 and 50 ton cranes, which lift the cars and tip the contents over the vessels' hold or by hydraulic hoists, which raise the car and tip the contents down a chute into the vessels' hold.

London & Northwestern Railway: Mr. J. B. Harper, Superintendent, states for handling baggage at stations there are a number of electric and hydraulic elevators, with subways serving the various platforms. At some stations, parcels and mail bags are handled in the same way. Freight warehouses are equipped with electric or hydraulic cranes, and sometimes with elevators, and at shipping docks cargo or freight is handled by hydraulic steam and electric cranes up to 30 tons capacity. For the coal traffic, the docks are fitted with coal hoists, and electric and hydraulic coaling cranes up to 40 tons capacity. There are also a few electrically-driven conveyors working from the quay, and conveyors fitted to the coaling

piers. At Middlesborough there is a conveyor machine for loading coal into steamers. The railway cars discharge the coal into a 30-ton bin beneath the track, feeding onto an inclined belt conveyor about 130 ft. long. The upper end of this is in a tower, where the coal is discharged into a hopper 30 ft. above the quay. This feeds a pan conveyor on a boom 55 ft. long, extending over the water, and hinged so that it can be lowered to reach a steamer's hatch or raised so as to clear the rigging. It can be swung 12 feet on each side of its center line, so as to spread the coal or to serve two adjacent hatches.

South Australian Government Railway: Mr. A. B. Moncrieff, Railways Commissioner, states that electric cranes are being fitted to the new freight sheds at Adelaide. Figs. 13 and 14 show a plan and section

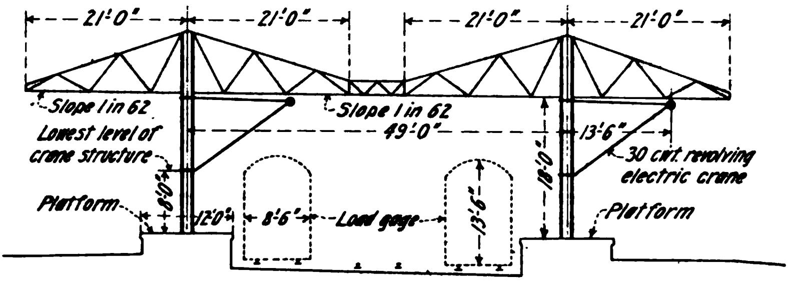


FIG. 14.

of a three-track outbound shed 600x91 ft. The cranes, Fig. 15, have a radius of 13 ft. 6 in., and are spaced 80 ft. apart along the platforms, being attached to the steel columns which support the roof.

FREIGHT AND CARGO HANDLING APPLIANCES AT FOREIGN PORTS.

As noted above, American seaports are much less completely equipped with freight and cargo handling appliances than are the large European ports, and the following particulars as to such equipment at some of these latter ports will be of interest.

Liverpool (Mr. Alfred Chandler, General Manager, Mersey Docks and Harbor Board): At the Princes Landing Stage, where the transatlantic steamers embark and disembark passengers, mechanical conveyors are used for the transfer of baggage to ships and cars. One of the bridges connecting the landing stage with the shore has a traveling platform in two parts, running in opposite direction. This is used for carrying the baggage trucks, the loaded trucks moving in one direction and empty trucks in the opposite direction.

For handling cargo the various docks have an extensive equipment

and hydraulic cranes of 3 to 100-tons capacity. The roof cranes avoid interference with the space on the dock front. There are also about 25 hydraulic coaling hoists, handling cars of 20 and 15 tons capacity (total weight 30 and 32 tons), and shipping coal at the rate of 300 tons per hour. Most of these travel along the dock wall. There is also a coaling dock capable of shipping 2,300 tons per hour. The new Gladstone Dock has 1½-ton semi-portal electric cranes and a 5-ton steam locomotive crane.

London: In reply to an inquiry as to the use of conveyors at the Tilbury Dock (a dock near the mouth of the Thames), Mr. R. Philips, General Manager of the Port of London Authority, states that the Port

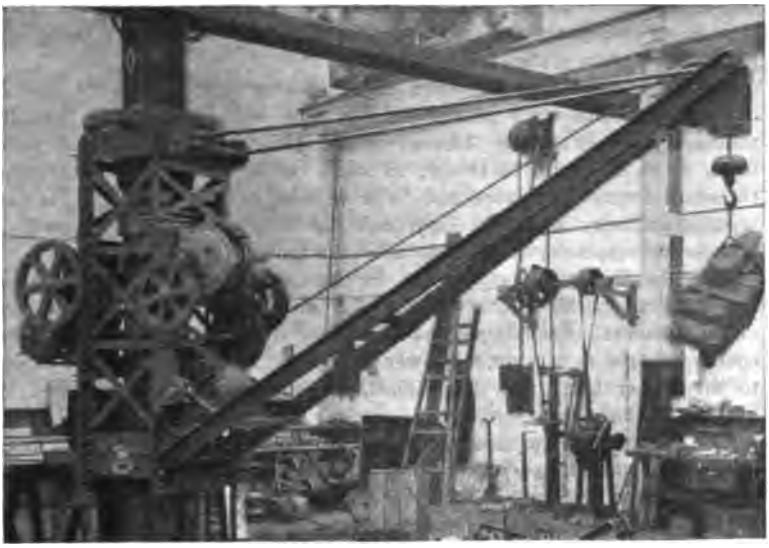


FIG. 15—TWO-MOTOR ELECTRIC JIB CRANE, SOUTH AUSTRALIAN RAILWAYS.

Authority owns no mechanical appliances for handling freight and cargo at this dock, but that a stevedoring firm (Scrutton's, Limited), has installed three conveyors worked by electricity:

(1) For carrying jute and other fibres in bales from a shed used for the storage of general goods into a shed set apart for the storage of fibres, a distance of 180 feet; (2) for discharging tea from a ship and conveying it into the warehouse. The sorting to marks is done by pushing the packages off at given points where men are stationed; (3) for discharging frozen meat and conveying it along the quay.

The delivery to barges or railway trucks for different destinations is accomplished by lifting the meat off the conveyor when the particular mark required reaches the point where the barge or railway truck is placed.

Manchester (Mr. E. Latimer, General Superintendent, Manchester Ship Canal Company): The crane equipment of the Manchester Docks includes 53 hydraulic, 64 steam and 109 electric cranes, varying in radius from 16 to 40 ft., with a lifting capacity of from 1 to 10 tons, to a height from rail level of from 13 ft. to 50 ft. There is also a 30-ton steam crane and a pontoon sheers capable of dealing with weights up to 250 tons with a lift of 21 ft.

An appliance which has proved of great utility in connection with the cargo handling cranes is the hatchway control gear. The crane operator is provided with a small controller which is slung from his shoulders and weighs about 7 lbs. By means of two handles fitted on either side, the lifting, lowering and slewing movements are under complete control. Attached to the switch is a flexible armored cable which passes to the crane ring posts and to the set of small collector rings, the motors being operated through a system of contactors.

By means of this appliance, the discharge and loading of vessels can be performed with greater rapidity and with more safety than by means of the old system. Instead of the crane man being located 30 to 60 ft. from the hold, he is able to stand beside the hatchway, carrying the small control apparatus, and to move with perfect freedom. He can without difficulty sight the load from the bottom of the hold until it is deposited upon the quay shed, railway wagon or barge.

At the Partington coal basin on the canal there are six hydraulic car-dumping machines for loading coal direct from railway cars into ocean steamers. Each tipple has a capacity of 300 tons per hour. The coal is brought in cars on the lower level lines, raised by hydraulic power to the higher level, and then tipped, the empty car being returned by gravity to the railway sidings.

At the Manchester docks, a 25-ton hydraulic crane has recently been erected for coaling vessels in the docks. This crane is of the center pillar or pivot type and is fixed on a concrete foundation. It is capable of performing the following operations:

(1) Lift and readily handle a load of 25 tons at a radius of 35 ft.

(2) Lift the load to a height of 25 ft. from the level of the railway on the wharf immediately behind the crane foundation to the lowest part of the inside of the cradle in any position.

(3) Slew 450 degrees in either direction.

(4) Raise a cradle carrying a standard 12-ton coal car from a horizontal position to an angle sufficient to discharge the coal quickly out of the wagon.

The crane is provided with a luffing jib capable of being raised and lowered under loaded or any conditions so as to vary the working radius of the crane to the extent of 12 ft. The operations of lifting, slewing,

for 40,000 tons of grain or 1,500,000 bushels. The No. 2 grain elevator, with a storage capacity of 40,000 tons, is now in course of construction. The building is being constructed throughout of reinforced concrete, with steel doors and window frames and the roof will be covered with asphalt, it will be fireproof throughout. The building will occupy the whole of the end of No. 9 dock and grain will be discharged from steamers berthed along the sides of the dock into subways which were constructed when the dock was made, and will be conveyed on bands into the elevator where it will be elevated and distributed to the various bins in the house. Provision will be made for 260 storage bins and for 81 shipping bins 76 ft. 8 in. deep. When the grain has to be delivered from the storage bins, it will be lifted and distributed to the shipping bins, from which it will be loaded either in bags or in bulk into barges, carts or railway wagons. Each of the receiving and shipping elevators will be provided with an automatic scale capable of weighing 200 tons per hour. It is expected that the new elevator will be ready for work early in the summer of 1914.

Bristol: (D. Ross-Johnson, General Traffic Manager.) The use of special mechanical appliances at the several docks at this city has not developed to an extent which would make a detailed description of them useful. At the Avonmouth Dock (near the river mouth), the passenger station is situated at the entrance lock and when the state of the tide enables the ship to enter, the baggage is discharged from the ship by means of chutes, placed by hand on trucks running on tracks, and taken into the Customs examination room where it is distributed on benches. After examination it is carried by means of rubber-tired hand trucks to the train platforms and loaded into the cars.

When a steamer misses the tide, the baggage is brought in tugs to the pier outside the lock, whence it is lifted by steam cranes onto the trucks, and dealt with as described. Mail sacks are handled in the same way.

Ordinary cargo is dealt with by cranes or ships' gear and hand trucks. Electric cranes travel above the roof of the piers from ships. Grain is discharged by means of bucket elevators either fixed on the quays or on floating pontoons, and discharged through trap doors to belt conveyors running in a tunnel below the surface of the quays, whence it is carried to the grain storage and elevators.

Hamburg: In a paper by Mr. Bubendy, Director of the Port, presented before the American Society of Mechanical Engineers during its visit to Germany in 1913, a very striking description was given of the cargo handling equipment, as shown by the following extract from a condensed translation of the paper, which appeared in the "Engineering News" (July 31, 1913):

"The modern pier sheds are 200 ft. wide in order that all the goods taken from one ship may be distributed opposite to it for further treatment. Railway tracks at the rear of the shed provide for carrying away the goods. All sheds are built of wood because steel structures would be far more expensive and in case of fire would be destroyed any way.

"The hoisting of the goods from the ships' hold is done by revolving jib cranes, of which there are 650. These cranes have an average lifting

capacity of 3 tons. The oldest of them are operated by steam, but 20 years ago the first experiments were made with cranes operated by electricity, and all cranes constructed since are electrically operated. These cranes move along the quay on two rails, one is placed close to the edge of the quay while the other one is along the wall of the shed above the doorways. The crane thus spans the railway track without obstructing to any great extent the working space on the pier.

"The great advantage of these cranes lies in their capability of adapting themselves automatically to any load. Owing to this and to their simplicity they perform work very economically. The lifting of the cargo and the swinging of the crane are done by separate motors, while for the movement along the quay manual labor is employed. There is at least one crane to every 65 ft. of pier. It often happens that two or even three cranes are taking cargo from one hatchway.

"Very recently the desire for greater rapidity in loading and discharging, thereby shortening the stay of the vessels at the pier, has led to the construction of double cranes. They consist of a revolving jib crane traveling on top of the pedestal and a trolley hoist or conveyor on the lower chord of the crane bridge. The jib crane will transfer goods of any kind and any volume from the ship's dock to the shed floor, while the capacity of the conveyor is limited to goods of lesser bulk, as sacks, parcels, bales and small boxes, the clear width between the legs of the tower being limited.

"The sheds along the quays are not supposed to store goods for any length of time. The cargoes taken from the ships are merely assorted here, to be conveyed immediately, either by boat or by rail to the warehouses of the city or inland. The number of vessels arriving at this port during 1912 was 18,500 with a register tonnage of over 14,000,000."

DESIGN AND OPERATION OF HUMP YARDS.

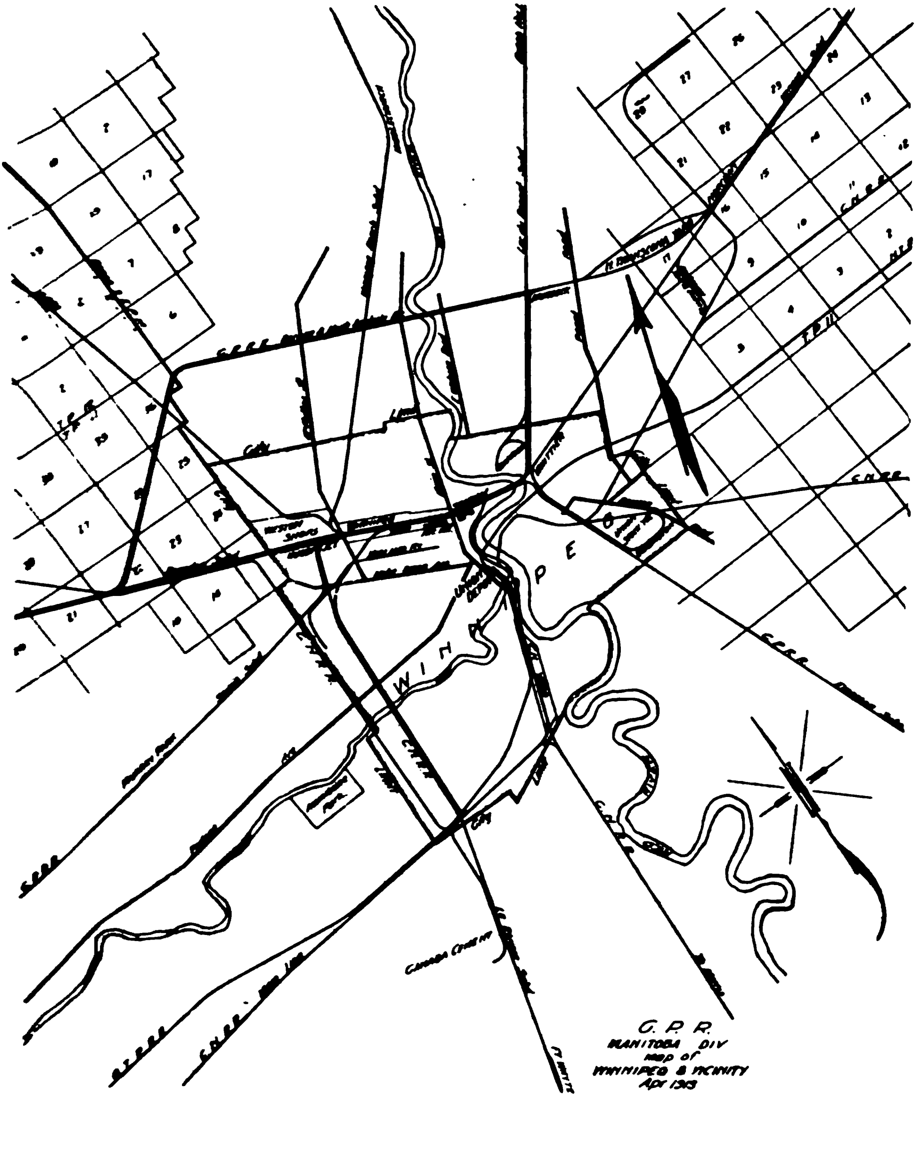
The Canadian Pacific Railway has recently completed a large hump yard at Winnipeg, Manitoba. The yard as built at present contains twenty (20) tracks in the westbound receiving yard, twenty (20) tracks in the westbound classification and departure yard, twenty (20) tracks in the eastbound receiving yard and twenty (20) tracks in the eastbound classification and departure yard, each track holding seventy-two (72) cars, making a total of eighty (80) tracks with a capacity of five thousand seven hundred and sixty (5,760) cars.

In addition to the above, there are forty-two (42) minor tracks, holding a total of one thousand one hundred and eighty-three (1,183) cars. Ten (10) of these tracks are used for a hold yard, eight (8) for caboose yard, twelve (12) for repair yard, four (4) for transfer yard, four (4) for icing yard and four (4) for coal storage yard. The engine yard has a capacity of twenty-four (24) engines.

When the yard is fully developed as designed it will have thirty (30) tracks in the westbound receiving yard, holding two thousand ninety (2,090) cars, forty (40) tracks in the westbound classification and departure yard, holding two thousand seven hundred and forty (2,740) cars, thirty (30) tracks in the eastbound receiving yard holding two thousand ninety (2,090) cars and forty (40) tracks in the eastbound

CANADIAN PACIFIC RAILWAY.

MAP OF PROPOSED CLEARING YARD AT NORTH TRANSCONA, NEAR WINNIPEG, MAN., CANADA.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map of
WINNIPEG & VICINITY
Apr 1913

yard of nine thousand eight hundred (9,800) cars. In addition to the above, there will be one hundred and sixteen (116) minor tracks, holding a total of two thousand seven hundred and fifty-five (2,755) cars used as follows:

24 tracks in WB. hold yard	Capacity	600 cars
24 tracks in EB. hold yard and grain	Capacity	1,160 cars
7 tracks in WB. yard	Capacity	40 cars
7 tracks in EB. yard	Capacity	40 cars
32 repair tracks	Capacity	410 cars
8 transfer tracks	Capacity	225 cars
6 icing tracks	Capacity	200 cars
8 coal storage tracks	Capacity	80 cars

The engine yard will then hold forty-eight (48) engines.

The engine terminals are located between the eastbound and westbound yards.

Present engine house contains forty-four (44) stalls, with room for eleven (11) additional stalls. Provision has also been made for an additional engine house of fifty-five (55) stalls.

The yard has two (2) humps. In each case track scales are located on the hump.

The arrangement of leads in classification yards next to the humps is planned so there will be a minimum of curvature for cars to pass through coming from the hump.

There are no separate departure yards, the trains being made up in the end of the classification yard furthest from the hump.

The yard is supplied with air, so that delay incident to road engines pumping up air on train after engine is coupled is avoided. Practically all frogs used in this yard are No. 7 with an angle of 8° 10′. Clear running tracks through the center of yard are provided for light engine movements.

Plan and profile of yard accompany this report.

In addition to the yard above described the following hump yards have recently been built, or are under construction:

Boston & Maine Railroad	Mechanicsville, N. Y.
Chesapeake & Ohio Railway	Silver Grove, Ky.
Chicago, Milwaukee & St. P. Railway	Air Line Yard, Milwaukee, Wis.
Louisville & Nashville Railroad	Radnor, near Nashville, Tenn.
Minnesota Transfer Railway	Minnesota Transfer, Minn.
New York Central & Hudson River Railroad	Gardenville, N. Y.
Norfolk & Western Railway	Bluefield, W. Va.

Circular letters asking for information relative to operation and construction of hump yards were sent out to all roads operating yards of this type, the following information being requested:

(1) Cost per car (for yard operation).

(2) Cost per car in old flat yard before hump yard was built, or cost in other flat yards as nearly comparable as possible, so that economies of the hump yard may be noted.

(3) The maximum number of cars put over the hump in any one hour, and the estimated capacity of the hump yard in 24 hours.

(4) Do you recommend any changes in grades on the hump as shown in the Manual?

(5) Is track scale located on hump? If not, where?

(6) How many cars should be handled daily to warrant the use of a hump yard?

(7) How do you determine the number of car riders required to handle cars on the hump; that is, have you any definite rule to determine the number of riders required to handle a certain number of cars?

(8) How do you employ car riders so as to secure the necessary elasticity when force is to be decreased or increased?

(9) What system are you using in hump coal yards to indicate to towermen or the men throwing switches what track the cars are to be placed on?

(10) Advise if this system is a success, and if not, what modification can you suggest?

(11) Do you consider departure yards desirable?

(12) Advise if you are using them.

(13) Please send print of plan and profile of each hump yard covered in the above report.

Reports were received from fifteen (15) of the leading railroads in the United States, giving data covering twenty-nine (29) hump yards, which is recapitulated as follows:

Question (1) 28 yards report an average cost in hump yard of 21.2 cents per car.

Question (2) 11 flat yards report an average cost of 22.91 cents per car.

Question (3) 22 hump yards report an average of 72 cars over the hump per hour.

24 hump yards report their average capacity per 24 hours at 1,973 cars.

Question (4) Of the 15 railroads reporting, 9 make no recommendations in regard to changing grade on hump; 1 submits plans of grades recommended, and 1 found it necessary to make changes in grades recommended in the Manual.

Question (5) Of the 15 roads reporting, 9 have scales on hump and 6 have no scales on hump. Of the 29 yards reported, 19 have scales on hump, 8 have scales in yard and 2 have no scales, either on hump or in yard.

Question (6) An average of the reports from 24 yards indicates that at least 800 cars must be handled daily to warrant the use of a hump yard.

Question (7) 24 yards regulate the number of car riders, according to business in sight; 4 have no definite rule and 1 figures on the basis of 7 cars per rider per hour.

Question (8) 23 yards maintain an extra list of car riders and draw on it as required; 4 yards maintain an extra list of switch tenders and use switch tenders for car riders as required.

Questions (9) and (10) 20 of the yards covered in this report use switch list to indicate cars cut off on the hump; 8 chalk track numbers on the ends of cars, and 1 uses telephone. All report the system they are using as successful.

Questions (11) and (12) Reports from 14 railroads covering 29 hump yards show that 16 yards have departure yards, and 13 have no departure yards. Reports from 28 of the yards favor the use of departure yards.

Key to Railroads may be had on Application to Secretary. Detailed answers to questions are shown as follows:

STATEMENT OF ANSWERS RECEIVED TO QUESTIONS (1), (2), (3).

Railroad	Yard	(1) Cost per Car Hump Yard	(2) Cost per Car Flat Yard	(3) Maximum number of cars put over hump in any one hour	(3) Estimated capacity of hump yard in 24 hours
A	....	.293	X	125	2,000
B	....	.075	.54	90	1,000
C	....	.135	.12 to .18	X	1,000
D	....	.16 Y	X	100	2,300
E	a	.11	X	60	1,000
	b	.37	X	60	888
	c	.21	X	70 to 80	1,625
	d	.36	X	40 to 70	900 to 1,200
F	a	.27	.32	100	1,200
	b	.275	.20 to .25	X	1,800
G	....	.165	.21	75	4,800
H	a	.4226	.34	120	2,300
	b	.508	X	35	1,200
I	....	.3501	X	50	700
J	a	.1128 Z	X	38	1,000
	b	.10 Z	X	50	1,200
	c	.09 Z	X	50	1,200
	d	.19 Z	X	50	1,200
	e	.074 Z	X	X	3,000
K	a	.158	X	60	X
	b	X	X	X	X
L	a	.2501	X	50 to 60	X
	b	.2092	.247	X	3,200-2 humps
M	a	.21	X	X	1,600
	b	.12	.13 to .19	100	1,500
	c	.351	X	Eastbound	2,400
	c	....	....	Eastbound	2,200
	c	....	....	Westbound, empty	3,100
	c	....	....	Westbound, loaded	1,200
N	....	.216	.121	100	1,700
O	a	.095	.12	105	X
	b	.079	.087	50	X

"X"—Figures not given.
"Y"—Also includes cost of car inspectors.
"Z"—Does not include cost of fuel, stores and locomotive supplies.
The cost per car for yard operation includes the wages of enginemen, firemen, conductors, yard brakemen (riders), car cutters, car markers, clerical forces in the yard, switch tenders and yardmasters, together with fuel and stores, except as above indicated.

Additional information in reference to questions is given in Appendix A.

LIST OF HUMP YARDS IN SERVICE AND UNDER CONSTRUCTION IN THE UNITED STATES AND CANADA SO FAR AS COMMITTEE HAS BEEN ABLE TO OBTAIN INFORMATION

NAME OF RAILWAY	LOCATION OF HUMP YARD	No. of Yards in Use
Baltimore & Ohio	Brunswick, Chicago Jct., Chicago, Cumberland, Connellsville, Fairmont, Holloway, Keyser, New Castle Jct	9
Belt Railway of Chicago	Chicago Clearing Yard	1
Boston & Maine	Worcester, Mechanicsville	2
Canadian Pacific	Winnipeg	1
Central of New Jersey	Allentown, Mauch Chunk (Gravity one way)	2
Chesapeake & Ohio	Russell, Ky., Silver Grove, Ky	2
Chicago & Eastern Illinois	Dalton, Salem	2
Chicago, Burlington & Quincy	Hawthorne, Galesburg, Lincoln, Neb	3
Chicago. Indiana & Southern	Gibson, Ind	1
Chicago, Milwaukee & St. Paul	Air Line Milwaukee, Godfrey	2
Cleveland, Cincinnati, Chicago & St. Louis	Harrisburg, Lyons	2
Delaware & Hudson	Oneonta, N. Y	1
Illinois Central	Centralia, Ill., Harahan	2
Kentucky & Indiana Terminal	Louisville, Ky	1
Lake Shore & Michigan Southern	Collingwood, Elkhart, Ind	2
Louisville & Nashville	Radnor, near Nashville	1
Michigan Central	Windsor, River Rouge, North Detroit, West Detroit	4
Minnesota Transfer	Minnesota Transfer, Minn	1
Missouri Pacific	Dupo, Ill., Kansas City	2
Nashville, Chattanooga & St. Louis R'y.	Atlanta, Nashville	2
New York Central	Avis, Dewitt, Gardenville, West Albany	4
Norfolk & Western	Bluefield	1
Peoria & Pekin Union	East Peoria	1
Pennsylvania Railroad	Altoona, Edgemoor, Enola, Ebeneser, Harrisburg, Hollidayburg, Honey Pot, Maryville, Pitcairn, Waverly, West Philadelphia, Youngwood, Northumberland	13
Pennsylvania Lines West (Southwest System)	Scully, Pa., Bradford, Ohio, Columbus, Ohio, Grand View, Ohio, Fulton, Under Cliff (both at Cincinnati, Ohio), Richmond, Ind., Logansport, Ind., 59th Street, Chicago	9
—Northwest System	Allegheny, Conway, Mansfield, Crestline, Chicago, Bedford, Cleveland, Wellsville, Shop	9
—Central System	Cambridge, Y. D. Yard, Lancaster	3
Philadelphia & Reading	Rutherford	1
Pittsburgh & Lake Erie	Glassport, Pa., Haselton, Ohio, McKees Rocks, Pa., Newell, Pa., Dickerson Run, Lynch	6
Southern	Asheville, N. C., Inman, Ga	2
Terminal of St. Louis	East St Louis	1
Union	Oak Hill, Pa	1
Washington Southern Railway	Alexandria, Va	1
Total		95

TRACK SCALES.

The Committee has received copies of the amended specifications issued by the American Railway Association, and are giving these careful consideration, together with such other data as they have been able to obtain during the past year, and recommends that the subject of track scales be continued for next year's report.

Respectfully submitted,

COMMITTEE ON YARDS AND TERMINALS.

Appendix A.

ADDITIONAL DATA IN REFERENCE TO QUESTIONS 1 AND 2.

Railroad A—In comparing hump yard with flat yard, it is entirely a question of efficiency.

Railroad I—Hump yards are not figured as an economy. They are an improved facility for the handling of cars, and possibly cost more to operate.

Railroad K—Taking the wages of men engaged solely in the work of classification, we show a decrease of 3.73 cents per car by the hump method, as compared with the old flat yard. There is no doubt in my mind but that with properly designed hump yard, with receiving, classification and advance yard for each direction, great economies can be effected both in expense and time. A great many operating officials in this section seem to think there is more damage to equipment and freight by the hump method than there was in the old flat yard, but in our opinion there is less.

Railroad L—Our experience shows that we have nothing we can compare the hump switching with. When we had a flat yard the switching was entirely different, in that we did not undertake to make the cuts and classifications we do now. We would hazard a guess that to do the clessification we do in the flat yard, the expense per car would be doubled, compared with hump switching.

Railroad M—Hump yard switching probably no lower per car, but yard for flat switching would need to be much larger.

Question (4) "Do you recommend any changes in the grades on the hump as shown in the Manual?"

(See Manual, Edition 1911, pp. 399 and 400.)

Railroad A—No.

Railroad B—No.

Railroad C—The grades as shown in the Manual seem to be about right, but I would not state definitely, as it often occurs that the grades have to be changed after the yard is laid out, as they are oftentimes not steep enough to give the cars proper momentum to run to the heels of the tracks in the classification yard. The best method is to lay a yard out in accordance with the grades suggested, and then change the grades after the hump is in operation, giving best degree of elevation, as will cover all requirements.

Railroad D—No.

Railroad E—No.

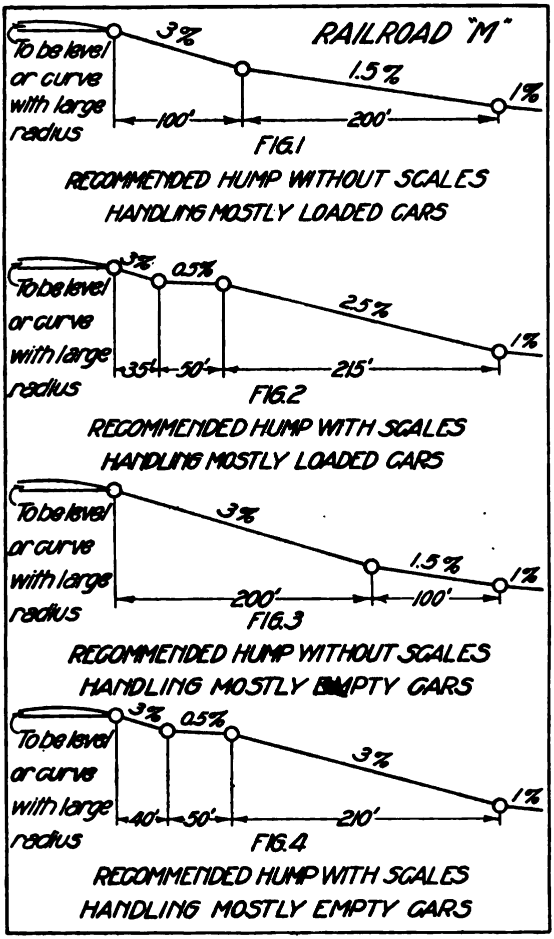
RAILROAD "J."

PROFILES OF SCALE HUMPS IN VARIOUS YARDS.

up grade into the receiving yard, and not require extraordinary heavy switching power to handle trains over the hump.

Railroad H—No.

Railroad I—The grades on any hump are governed by the class of business handled over them. Empty or located equipment, or both.



Railroad J—No.

Railroad K—No.

Railroad L—No.

Railroad M—When cars to be classified are mostly loaded and hump without scales; 3 per cent. descending for 100 ft. from summit,

200 ft. descending 1.5 per cent., thence 1 per cent. descending through switches. For hump with scales, cars mostly loaded, 35 ft. of 3 per cent. descending from summit, 50 ft. of 0.5 per cent., descending 215 ft. of 2.5 per cent. descending, thence 1 per cent. descending through switches. For hump without scales, cars mostly empty, 200 ft. of 3 per cent. descending from summit, 100 feet of 1.5 per cent. descending, thence 1 per cent. descending through switches. For hump with scales, cars mostly empty, 40 ft. of 3 per cent. descending from summit, 50 ft. of 0.5 per cent. descending, 210 ft. of 3 per cent. descending, thence 1 per cent. descending through switches.

Railroad N—Think the grades on the hump are subject to change to adapt them to the business to be handled over it, and also to the locality. Climatic conditions affect the running of cars very materially, and in more northerly locations where the winters are more severe, steeper grades are required than in locations where warmer temperature prevails. The grades on the hump should also be adapted to the kind of business to be handled; for instance, if only loaded cars are passed over the hump lighter grades can be used than if empties are to be handled. The recommendation in the Manual is a fair average.

Railroad O—Yard (a)—No.

Yard (b)—Depends upon condition. Original grade was constructed as recommended in the Manual. This was found too high and steep, and necessitated several changes. These changes made, and grade is now satisfactory.

Question (5) Is track scale located on hump? If not, where?

Railroad A—Automatic scales are located one mile south of the hump. Incoming trains pull over the scale when entering the receiving yard.

Railroad B—Scale is on hump.

Railroad C—One track scale on hump; one in city yard and one in shop yard.

Railroad D—Scale not located on hump, but on parallel track 300 feet in advance of hump.

Railroad E—Scales on hump in three yards. No scale in fourth yard.

Railroad F—Scale on hump in both yards.

Railroad G—Scale not located on hump. Scales located on outside track in both classification yards.

Railroad H—Scale on hump in both yards.

Railroad K—Yard (a) Scale is on hump.
Yard (b) Scale is not on hump.

Railroad L—Yard (a) Scales are located in classification yard in westbound yard on outside lead near end of yard, and about the same location in eastbound yard. The locations of scales were not changed when hump yard was built, but are reasonably convenient for use under our method of operation. Very little through business required to be weighed is switched over the hump.
Yard (b) Scale not located on hump. Located at east end of eastbound classification yard.

Railroad M—Yard (a) Scale on hump.
Yard (b) No scale in this yard.
Yard (c) Scales located on both eastbound and westbound humps.

Railroad N—Scale not located on hump. Located in middle of yard.

Railroad O—Yards (a) and (b) Scale on hump.

Question (6) How many cars should be handled daily to warrant the use of a hump yard?

Railroad A—There would be no economy unless there were at least 600 cars to handle daily.

Railroad B—700 cars.

Railroad C—There should be at least 500 or 600 cars on hand in yard at all times to warrant the successful use of a hump yard.

Railroad D—500 cars.

Railroad E—Yard (a) Have no recommendation as to minimum number of cars warranting the use of humps.
Yard (b) To warrant the use of hump to handle loaded cars to weigh, the crew, consisting of conductor and nine brakemen or riders with two engines, and two switch tenders, 685 loaded cars must be handled in 24 hours. For the operation of the same hump handling empties, with the same crew and one engine and two switch tenders, 580 empty cars must be handled in 24 hours.
Yard (c) Depends entirely upon the classification required.
Yard (d) Where prompt weighing and classifying of cars is desired, the hump is warranted for any number of cars.

Railroad F—Yard (a) 500 to 700 cars.
Yard (b) According to conditions; 500 to 800 cars.

Railroad G—According to the number of classifications desired. Would say 1,500 cars to a single hump.

Railroad H—Yard (a) 2,000 cars.
Yard (b) 1,400 or more.

Railroad I—At least 500 cars.
Railroad J—Yard (a) 500 cars.
(b) 750 cars.
(c) 750 cars.
(d) 750 cars.
(e) About 500 cars.
Railroad K—(a) Not less than 750 cars.
Yard (b) 600 cars.
Railroad L—Yard (a) Depends largely upon the number of classifications desired. If classification will not exceed five to seven, should say flat switching most economical from wage standpoint. Only up to about 1,000 cars per 24 hours.
Railroad L—Yard (b) The number of switches made, rather than the number of cars handled, would determine. It is felt that 800 switches per 24 hours period would warrant the use of a hump.
Railroad M—Yard (a) 350 cars in 11 hours.
(b) 350 cars.
(c) From experience, we would say that when the volume of business is less than 1,000 cars in 24 hours, flat yard operation is more economical, and above 1,000 cars per 24 hours warrants the use of the hump yard.
Railroad N—1,500 cars.
Railroad O—Yards (a) and (b) We have no information other than estimates furnished by Superintendents operating hump yards. Information furnished by them shows estimated average of 550 cars.

Question (7) How do you determine the number of car riders required to handle cars on the hump; that is, have you any definite rule to determine the number of riders required to handle a certain number of cars?

Railroad A—We get a line up just before each shift, as to the probable number of cars that will arrive, and regulate the number of riders accordingly.

Railroad B—We have no definite rule. Number of riders depend entirely upon the condition.

Railroad C—In ascertaining the number of car riders required, it is necessary to start in with about 15 riders and a foreman, and then cut down in accordance with the business handled. At present we have 10 riders and 1 foreman. If business increases, the riders are increased by taking men off of extra runs. When business decreases the extra men are taken off. When there is little business in the light yard on southbound traffic, the riders are taken from this yard and placed in the loaded yard, and handle work over the northbound

hump helping out the other riders. By this method it helps out the northbound when the southbound is light, and vice versa, and insures maximum efficiency from complement of riders cutting out idle periods.

Railroad D—The number of riders is determined by the number of cars to be handled.

Railroad E—Yard (a) In this particular yard we use one crew of conductor and five brakemen days, and one crew of conductor and three brakemen nights. We have no definite rule for determining the number of car riders, except that of experience.

Yard (b) We figure that each rider will handle seven cars per hour, which requires nine riders at the rate of sixty cars per hour.

Yard (c) Depends entirely upon the amount of business being handled. Extra men are called as needed.

Yard (d) Number of riders depends solely upon the business being handled.

Railroad F—Yard (a) Depends upon business. Ten men will keep train moving without hump engine being required to stop and wait for riders. We never work less than eight riders.

Yard (b) No definite rule to determine the number of riders. Increase number of riders to increase movement of cars over hump.

Railroad G— Determined by the number of cars reported coming. When receiving yards are worked to nearly full capacity, we work 20 men on an engine in the day and 18 men nights. Three of these men, conductor, pin puller and man following the engine, do not ride.

Railroad H—Yard (a) Determined by number of trains in the yard, and the number due to arrive, figuring on calling one rider to 50 cars.

Yard (b) Sufficient number to enable switching cuts fast enough to keep up with the business received.

Railroad I— Determined by number of cars on hand, and number in sight to be handled over the hump.

Railroad J—Yard (a) No definite rule to determine the number of riders to handle a certain number of cars. This is a matter which is controlled largely by the business handled through the yard, by the amount of switching to be done, and the distance that the riders are required to walk from classification yard to new hump. In the yard our business is regular, and as a general proposition, the same number of men are required each day.

Yard (b-c-d)	One man for each cut; the cut may consist of one car or more than one.
Yard (e)	Governed by conditions of yard and reports of trains in transit.
Railroad K—Yard (a)	By the volume of cars on hand and in sight, and the general condition of the yard and business.
Yard (b)	No definite rule. Regulated on the judgment of the Trainmaster, according to the amount of business in sight.
Railroad L—Yard (a)	We figure on a maximum of 18 and a minimum of 15, according to the amount of business on hand and in sight, and to be handled for the subsequent twelve hours.
Yard (b)	Regular assignment of men to the humps is based on minimum of an average day's work. Extra men report mornings and evenings to increase the riders if necessary. Number of cars on hand in receiving yard and the number of trains coming, as well as weather conditions, govern.
Railroad M—Yard (a)	No rule. About three minutes to a round trip. Four cuts per minute equal twelve riders.
Yard (b)	No rule. Seven riders at two cuts per minute.
Yard (c)	We employ check clerks on the hump to keep accurate daily record of the individual performance of each car dropper, from which we determine the average number of cars and cuts per man that can be ridden over the hump into the classification yard for a day's work under normal conditions. This gives us a basis for comparison, and enables us to determine the number of car droppers required, by first ascertaining how many cars we have in the yard to be shifted. Also how many cars we have approaching this yard that may come in within the next twelve-hour period. For example: On a hump where the car dropper averages twenty cuts and forty cars per man in a twelve-hour period, 1,000 cars in sight to be shifted within the next twelve-hour period, we would assign a force of 25 car droppers on that particular hump.
Railroad N—	Increase or decrease from extra list to handle the business.
Railroad O—Yards (a-b)	Have no set rule. Number of riders is determined by the yardmaster after information is furnished by dispatchers as to the probable number of cars in sight.

Question (8) How do you employ car riders so as to secure the necessary elasticity when force is to be decreased or increased?

Railroad A—Our men are employed as switchmen, and hold seniority on all jobs pertaining to the yard.

Railroad B—We have eighteen riders, of which ten are regular men. The other eight are called as needed. The eighteen men represent day and night forces combined.

Railroad C—Extra car riders are taken occasionally from the extra list and used on the hump during the day, using a new man each day, and by this method it is only a short time before twenty-five or thirty men on the extra list have become proficient for service in the capacity of hump riders.

Railroad D—We carry an extra force; increases and decreases are made from the extra force.

Railroad E—Yard (a) No answer.

Yard (b) Riders are drawn from extra list of yard brakemen maintained.

Yard (c) Taken from the extra brakemen maintained.

Yard (d) Taken from the reserve of extra list of yard brakemen.

Railroad F—Yard (a) Governed entirely by the amount of business and number of cars required to be put over the hump.

Yard (b) Car riders are employed as switchmen. The fluctuation in force of car riders identical with the increase or decrease in number of switch engines.

Railroad G— In employing men we require two years' previous railroad experience in train or yard service. Inexperienced new men throw switches until such time as yardmasters consider them competent to ride. They make the best riders.

Railroad H—Yard (a) By an established regular force with large extra list.

Yard (b) Experienced men assigned by yardmaster. In reducing forces or adding to forces older experienced men retained on humps.

Railroad I— We use the regular yard brakemen.

Railroad J—Yard (a) When necessary to increase the number of riders on the hump, this force is drawn from our list of extra brakemen.

Yards (b-c-d) Our men are paid brakeman's wages, and if called out get paid for a day, whether they work or not.

Yard (e) We carry about twenty-five extra men at all times, and fill humps from this force as required.

Railroad K—Yard (a) We carry a comparatively large extra list, and have no trouble in decreasing or increasing the force as circumstances warrant.

Yard (b) Number of riders regulated from day to day according to the run of business.

Railroad L—Yard (a) We maintain a force of twelve to fifteen extra yard brakemen, days and nights, to draw upon when necessary to increase number of hump riders.

Yard (b) Minimum number of car riders assigned to regular service each trick, number being increased from extra force, reporting each morning and evening as necessary.

Railroad M—Yard (a) We have a large extra force which may be called as needed. Called for one day only in each case.

Yard (b) Extra men sufficient force.

Yard (c) We have a regularly assigned shifting crew on each hump, consisting of the minimum number of car droppers required to handle the business at the respective points under any conditions. We also carry a force of about 120 extra yard brakemen, who are used to fill vacancies of regular men off duty, also to increase the force on the various humps by assigning the additional number of brakemen required daily to handle the volume of business in sight. For example, a hump crew having fifteen regularly assigned car droppers may have five of the regular men off duty and may require a total of twenty car droppers to take care of the business in sight on a given date, in which event a total of ten extra men would be assigned to that crew, five of them to fill the vacancies and five additional men required.

Railroad N— Increase or decrease from extra list to handle the business.

Railroad O—Yards (a-b) Car riders are employed as switchmen, and when necessary to increase force men are taken from extra board.

Questions (9) and (10) What system are you using in hump yards to indicate to towermen or the men throwing switches what track the cars are to be placed on? And advise if this system is a success, and if not, what modification can you suggest?

Railroad A—We use the regular conductors' switch list, the hump foreman retaining the original list of tracks being shoved, and making a cut list for the pin puller and for the towermen. This system is an absolute success, and is the only practical method which should be employed in hump operation.

Railroad B—Switch tenders are furnished switch list. Successful.

Railroad C—The hump foreman on hump has a slip with the numbers, and opposite the numbers is the destination of each car on slip. Having permanent tracks for each and every classification, he knows into which track each car should go, and the three branch tenders are furnished a small slip with just the track numbers thereon. For instance: the first cut over hump goes into track No. 3, the first figure on this slip being "3," he throws the switch for track No. 3; the next cut for track 8. No. 8 being the next track number on his slip, he throws the switch for track No. 8, etc. The system of having branch tenders furnished with a slip stating into which track each cut is to go, is a success at this terminal.

Railroad D—Hump conductor, car cutter and switchmen are furnished with a switching list, made up by the car marker, who marks the car. Successful.

Railroad E—Yard (a) Switch tenders furnished list showing standing of cars in train to be broken up, and how many cars in each cut, with number of tracks cars have to go on. Successful.

Yards (b-c-d) Switch tenders are furnished a list on which is designated the cuts and tracks. Successful.

Railroad F—Yard (a) Men controlling switches are furnished with list showing the make-up of train. In addition, last car in cut is chalk-marked on end to indicate as to what track the next cut is to go into.

System is a success.

Yard (b) All cuts of cars are marked with chalk on ends, showing the track number on which the next cut is to be placed. A cut of cars coming down off the hump with the figure 10 marked with chalk on the end of car indicates that the next cut of cars is to go on track 10.

It is successful, and the only method we have found to overcome the mishandling of cars.

Railroad G— All cars are carded showing connection or destination. Classification track for first car is given by hand signal, and this car and all others,

as they leave the hump, are chalked on end and side where following car is to go, switch tenders using signs for each track. This system is the best we know.

Railroad H—Yard (a) By chalking two track numbers on the head car of each cut, one number indicating to signalman or men operating switches in tower track number for immediate cut, with hump properly illuminated at night so that numbers can be plainly seen. Present method very successful.

Yard (b) Tab system. Cuts are carded and tab of number of cuts and number of cars in each cut put in switch tenders' and pin pullers' hands.
System is satisfactory.

Railroad I— Switches operated by switchmen on ground. Chalk marks are used during the daylight on car ahead to indicate where the following car is to go, and lamp signals at night. This system is a success where we are using it if switches are close to the hump. Where switches are some distance from the hump and more than two switch tenders used, switch list would be made.

Railroad J—Yard (a) Switches on hump and in classification yard are handled by the car riders or switchmen, each man being given a list of the tracks where the various cuts of cars are to be placed, and the car riders handle the switches on their return from the classification yard to the hump. Our system seems to work very successfully, and we have no modification to suggest.

Yards (b-c-d) Switching cards. This system is a success.

Yard (e) Telephone system. Successful.

Railroad K—Yard (a) A list is made by the foreman for each switch liner showing track to which each cut goes. As our receiving track parallels the classification tracks there is no trouble or delay in the foreman getting the lists to the liners.
This system is a success.

Yard (b) Cars are switched by tags, and from these a switch list is made by foreman to be used by one switchman, who sets switch by hand, and indicates to men making cut how many cars to cut off each time. Works very well here, and same thing would have to be done where switches are

operated by power; that is, towermen who throw switches would have to be furnished with list of cars.

Railroad L—Yard (a) We furnish each switch tender with a list of each train showing track each cut is to go upon. System successful.

Yard (b) Switching lists made in sets of four, one for conductor cutting the car off, and one for each switch tender below the hump.

System is a success.

Railroad M—Yard (a) Four cards must be made out for conductors and switchmen to show cuts. System is successful.

Yard (b) Cars are marked on front end. System is successful.

Yard (c) In connection with each hump, we have a man designated as car marker, who is rated as a conductor, who goes over each train in the receiving yard, taking the card waybills with him, chalk-marking the cars, showing the tracks to which they are to be shifted in the classification yard. In addition to this, the car marker also makes out what is termed a "cut report," form C. T. 150 to correspond with the chalk-marks on the train, showing how many cars are in each cut for the various classification tracks when train is pushed over the hump. The "cutter" who uncouples the cars in each cut as they pass over the hump, is governed by the chalk-marks placed on the cars by the car marker, and the cut card, above referred to, has been placed in the hands of the towerman, who operates the switches for classifying the cars, so that the towerman knows in advance how many cars and cuts are in each train, also what tracks they are marked for. We have electro-pneumatic switches on each hump, equipped with indicators that are directly in front of the towerman operating the switches and showing him when cars foul and clear the various switches; therefore, the cut cards and indicators enable the towerman to operate the switches successfully in foggy weather without having to depend on looking out to see when cars clear switches for a following movement.

This system has proven very successful, and we suggest no modification.

Railroad N— Signal for destination of first car going over hump is given to junction switch tender. This first car is chalk-marked with the number of second car. Junction switch tender reads marking on car for next following, and conveys the information to switch tenders by hand or lantern signal where next car is to go.

System is successful.

Railroad O—Yard (a) Track number is chalked on rear side and end of each cut indicating the track that the next cut is to go into. Switches are handled by switch tenders in the field. Chalk system gives satisfactory results.

Yard (b) By day, hand signals are used to indicate track number to switch tender; at night, cars are chalked on right rear corner of each cut, showing the number of the cut which is next to be used. Switches are handled by switch tenders in the field.

The chalk system gives satisfactory results.

Questions (11) and (12) Do you consider departure yards desirable? And advise if you use them.

Railroad A—Departure yards are desirable. They relieve the bottom of the hump promptly, and relieve from danger of blockade in the operation of the hump.

We are not using them at present, but we have one about half-graded.

Railroad B—We do not consider them desirable.

We are not using them.

Railroad C—Yes, we do consider a departure yard desirable, as we can place caboose on rear of train and have train ready for movement as soon as engine is attached; while on the other hand, if trains were run out of classification yard it would be rather difficult to place caboose on rear of train while cars are still running in that particular track, and should the Motive Power Department fall down on engines to take trains out of classification yard, there would be no room in these tracks for cars going over the hump; but having a departure yard trains can be hauled to it, thus making switching room.

We are using departure yard.

Railroad D—Departure yards are desirable.

We are using departure yards.

Railroad E—Yards (a-b-c-d) Departure yards are desirable.

We are not using departure yards.

Railroad F—Yard (a)	Departure yards are desirable. We are not using departure yard.
Yard (b)	Decidedly yes; departure yards are desirable. We are using departure yards.
Railroad G—	Departure yards are desirable. We are not using departure yard.
Railroad H—Yds. (a-b)	Departure yards are desirable. We are using departure yard.
Railroad I—	Departure yards are desirable; in the case of an overflow from the classification yard. We have a delta yard located beyond the classification yard, which takes care of the overflow when any.
Railroad J—Yard (a)	We consider departure yards desirable where business is sufficient to warrant. We are not using departure yards.
Yards (b-c-d)	We consider departure yards desirable. We are not using departure yards.
Yard (e)	We consider departure yards desirable. We are using departure yards.
Railroad K—Yds. (a-b)	We consider departure yards desirable.
Yard (a)	We are using departure yards.
Yard (b)	We are not using departure yards, but have new yard under construction which will be used as one.
Railroad L—Yard (a)	We consider departure yards desirable. We are using departure yards.
Yard (b)	We consider departure yards desirable. We are not using departure yards.
Railroad M—Yard (a)	Yes, for safety of crews in making up trains. We are using departure yards where they can be built.
Yard (b)	We consider departure yards desirable. We are not using departure yards.
Yard (c)	Yes, particularly at this point. They serve the purpose of promptly relieving the classification tracks, thereby making room to keep up a steady movement for classifying over the hump without interference; also, having the advantage of coupling up the air hose and testing the air in the departure yard (or advance tracks), thus eliminating the danger of performing this work on the classification track, while cars would be dropping over the hump on the same track where this work would necessarily have to be performed if there were no departure yard. In this connection there has always been a difference of

	opinion among operating people on this railroad, as well as other railroads, with reference to the question of departure yards or advance tracks. However, I believe the question of operating with or without departure yards depends largely on the location of the operation, as well as the volume and kind of traffic handled.
	We are using departure yards.
Railroad N—	We consider departure yards desirable.
	We are using departure yards.
Railroad O—Yards (a-b)	We consider departure yards desirable.
	We are not using them.

REPORT OF COMMITTEE IV—ON RAIL.

J. A. ATWOOD, *Chairman;*
E. B. ASHBY,
A. S. BALDWIN,
J. B. BERRY,
M. L. BYERS,
CHAS. S. CHURCHILL,
G. M. DAVIDSON,
F. A. DELANO,
P. H. DUDLEY,
C. H. EWING,
C. F. W. FELT,
L. C. FRITCH,
A. W. GIBBS,
A. H. HOGELAND,
W. C. CUSHING, *Vice-Chairman;*
C. W. HUNTINGTON,
JOHN D. ISAACS,
THOS. H. JOHNSON,
HOWARD G. KELLEY,
C. F. LOWETH,
H. B. MACFARLAND,
R. MONTFORT,
C. A. MORSE,
J. P. SNOW,
A. W. THOMPSON,
R. TRIMBLE,
GEO. W. VAUGHAN,
M. H. WICKHORST,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Rail submits the following report:

The work outlined by the Board of Direction for the year was as follows:

(1) Recommend standard rail sections.
(2) Continue investigation of rail failures and deduce conclusions therefrom.
(3) Continue special investigation of rails.
(4) Rail joints.

During the year the following meetings were held: At Atlantic City, June 23, attendance 14; at Pittsburgh, September 26, attendance 11; at New York, November 5, attendance 15; at Chicago, November 14, attendance 19.

(1) STANDARD RAIL SECTIONS.

The subject of rail sections is under consideration by Sub-Committee B, R. Trimble, Chairman.

The information gained to date by the study of the present A. R. A. standard rail sections, types A and B, is not such as to warrant the Committee in recommending changes at this time in those standards.

The question of sections heavier than 100 lbs. has been under consideration, but no definite conclusions were reached concerning such sections, but the Committee expects to give this question further consideration during the coming year, and a Sub-Committee has been appointed for this purpose.

The investigations of the Committee up to this date indicate the inadvisability of railroads purchasing rails of lighter sections than 80 lbs.

per yard for replacements in main tracks on districts thereof that have conditions or traffic which places them under Class "A" or Class "B," according to the classification of railroads of the American Railway Engineering Association (see page 14, Manual).

(2) STATISTICS OF RAIL FAILURES.

Statistics of rail failures for the year ending October 31, 1912, were prepared by Mr. R. Trimble, and are given as Appendix A, having been first issued in Bulletin No. 157 for July, 1913.

The responses this year were more complete and in better form than ever before. Attention should be called, however, to the fact that many roads showed some carelessness in reports, particularly the "Position in Ingot" report. The requests for reports prepared so that they could be blueprinted was in many cases disregarded.

The fact has been noted by the Committee that failures in base of rails have been few in rails of comparatively thick base, like A. R. A. "B" type. Some railroads using rails of the thin base type have recently increased the fillet between the web and the base, to secure additional material at that point. A study of these details of rail sections, as well as of the means for avoiding seams in the base of rails during manufacture, will be continued by the Committee.

Mr. Wickhorst has given the subject of mill practice careful study and endeavored to connect up failures, as reported by the railroads, with the practice at individual mills, but finds that the forms on which the reports are made by the railroads make it impossible to accurately do this, and for this reason forms 408 and 411 have been revised in order that proper information may be available. These forms have been printed and distributed to the railroads for use in making current reports. The reports for this year to be made October 31, 1913, will, if properly made out on the new forms, give information covering several years, which will enable Mr. Wickhorst, who will hereafter compile the statistics of rail failures, to work out valuable results. The Committee is of the opinion that there are differences in mill practice which lead to differences in rail service, but find that it is not now in position to state definitely what those differences are. It proposes, however, to continue its investigations along this line. New form 408 is shown in Appendix I, and the Committee asks that the Association adopt it as a substitute for old forms 408 and 411, and for printing in the Manual at the proper time.

(3) SPECIAL INVESTIGATIONS.

During the year 1913, special reports or papers were presented to the Rail Committee as follows:

No. 34, January, 1913, by M. H. Wickhorst, Influence on Rails of Amount of Draft in Blooming (Bulletin 159). See Appendix B.

No. 36, April, 1913, by H. B. MacFarland, Influence of Seams or Laminations in Base of Rail on Ductility of Metal (Bulletin 160). See Appendix D.

No. 37, June, 1913, by M. H. Wickhorst, Seams in Rails as Developed from Cracks in the Ingot (Bulletin 160). See Appendix E.

No. 39, October, 1913, by M. H. Wickhorst, Influence of Aluminum and Silicon on Bessemer Ingots and Rails (Bulletin 163). See Appendix F.

Each report contains a summary of the matter contained in it, but below is given a very brief digest of the main results obtained.

Report 34 gave the results of an investigation made at Bethlehem, Pa., at the works of the Bethlehem Steel Company, concerning the influence on the finished rail of the amount of draft in rolling the ingot into a bloom and particularly with reference to the transverse ductility of the base and the presence of seams. A series of five ingots of one heat was rolled into rails in a similar manner, except that the draft used in making the bloom from the ingot was varied from about 3 in. per pass in the initial passes down to about 0.4-in. per pass in the early passes as the smallest rate of reduction used. The rails made with initial drafts in blooming of 3 in. and 1.5 in. contained a larger number and deeper seams in the base than those made with 0.8-in. or less of initial draft. This resulted in poorer results in the drop tests and transverse tests of the base in rails made with the heavier drafts. These results should be considered only as indicative, and final conclusions should be withheld until sufficient work has been done along this line to warrant them.

Report 35 gave the results of an investigation made at Steelton, Pa., at the works of the Pennsylvania Steel Company, comparing rails made of acid open-hearth steel with rails made of basic open-hearth steel, and also concerning the influence on rails of re-heating blooms that had been allowed to become cold. This investigation was not extensive enough to detect small differences, but in a general way it may be said that rails from basic open-hearth steel and from acid open-hearth steel gave about the same results in the drop test and in transverse tests of the base. Also rails from re-heated cold blooms gave about the same results as rails from wash-heated hot blooms.

Report 36, by H. B. MacFarland, Engineer of Tests, Atchison, Topeka & Santa Fe Railway System, gave the results of investigations concerning the influence of seams or laminations in the base of rails on the ductility of the metal and their relation to rail failures. This paper showed the decrease in transverse strength and ductility caused by seams in the base and indicated that seams are the origin of rail failures such as broken rails and broken bases.

Report 37 gave the results of an investigation made at Bethlehem, Pa., at the works of the Bethlehem Steel Company, concerning the development of seams in billets and rails from cracks in the surface of the ingot. This work showed that cracks on the right and left sides of the ingot as it first entered the blooming rolls resulted in seams in the rails, while cracks on the top and bottom sides of the ingot did not

result in seams. It indicated that the seams may thus be made to appear on the sides of the rail or on the tread and the bottom of the base. The cracks in the ingot were in a general way transverse or obliquely transverse of the ingot. When first bloomed, the cracks on the right and left sides of the ingot opened up or "yawned" open, forming double V's, one inside the other. Further blooming elongated and closed in the cracks, forming them into elongated Y shaped flaws, or clusters of them. Still further rolling finally resulted in long, narrow Y shaped seams in the rail, or cluster of them, generally several feet long.

Report 39 gave the results of an investigation made at South Chicago at the South Works of the Illinois Steel Company, concerning the influence of aluminum on bessemer ingots and rails when added to the molds while pouring the steel. It also gave the results of a few tests concerning the influence of silicon on bessemer rails when added as ferro-silicon to the molds. According to this work, ingots treated with aluminum as mold additions, were of more even composition throughout the ingot than plain Bessemer steel. There was less positive segregation in the interior and upper part of the ingot, but the negative segregation or soft center in the interior and lower part of the ingot was about the same. There was a softening or negative segregation in the upper part of the wall of the plain ingot, while in the aluminum treated ingots the walls were of fairly even composition throughout the height of the ingot. Aluminum treated ingots had larger and deeper pipes than plain steel, but had denser steel around the pipes. Rails of plain steel had a brittle zone in the upper part of the bar, as disclosed by the drop test. In rails of aluminum treated steel, this zone was largely eliminated. Rails of plain steel contained their interior laminations close to the top end of the bar, while in aluminum treated rails the interior laminations were found a considerable distance from the top end, varying from about 30 to 45 per cent. of the weight of the ingot.

In addition to the work done by Mr. Wickhorst, the Committee has endeavored to have the manufacturers publish the results of some of their own special investigations into the characteristics of rails under different processes of manufacture, and the Committee hopes to be able in future to present some such reports.

The general line of investigation which the Committee has in view for Mr. Wickhorst is submitted below and embraces a great deal more work than he can cover in any one year, but it is well to keep before us the subjects which are important and demand attention.

The main point kept in mind in the work of the last few years has been to conduct it so as to bring out information useful in improving rails for the purpose of making them uniformly safe, and it is probable that this must continue to be our guiding principle for some time to

Several years ago, at the time our Committee took up its experimental work, our information as to the causes of rail failures was in very indefinite shape, but we have now arrived at a point where we may feel considerable confidence that we have the correct diagnosis of the causes of most of the rail failures. Most of the failures may be divided into four classes, as follows:

(1) Crushed and split heads;
(2) Broken rails (square and angular breaks);
(3) Broken bases (crescent breaks);
(4) Transverse fissures (oval spots in rail head).

Our investigations show that crushed and split heads are attributable to the interior condition of the ingot from which the rail was rolled, known as segregation. This is an excessive concentration of carbon and phosphorus in the interior and upper part of the ingot and is to be avoided by obtaining well deoxidized quiet setting steel, and by not using ingots with "horny" tops.

Investigation seems to indicate that broken bases and at least a very large per cent. of broken rails have their origin in seams in the bottom of the base. Our work during the past year shows that such seams (at least a part) start from cracks in the surface of the ingot and are produced in the process of making the bloom, and that the details at this stage of the rolling are very important.

These three types of failure include about 90 per cent. of the rail failures of the country and are thus to be traced to the ingot and the initial stages of the rolling.

The other type of rail failures, transverse fissure, or oval spot in the rail head, we are as yet unable to state the cause of, but we expect to give this matter considerable attention during the coming year.

There is still another type of failure, cracked web, that we have but little definite information about.

Among the subjects needing investigation, the following may be listed:

SUBJECTS FOR INVESTIGATION.

Making Ingots.

(1) Influence of height of ingot on segregation and interior cavities, open-hearth steel.
(2) Influenced diameter of ingot, open-hearth steel.
(3) Influence of rate of pouring the ingot.
(4) Influence of temperature of liquid steel when poured into the molds.
(5) Influence of thickness of mold.
(6) Influence of taper of mold on ingot cracks.

Making Rails.

(7) Influence of temperature of rolling on high-carbon open-hearth rails.
(8) Causes of seams in base of rails.
(9) Influence of rate of reduction in rolling.
(10) Relation between shrinkage and grain size.
(11) Influence of methods of cooling on cooling beds.

(12) Effect of cold straightening rails.
(13) Influence of length of time in soaking pit on grain size and other rail properties.

Composition.

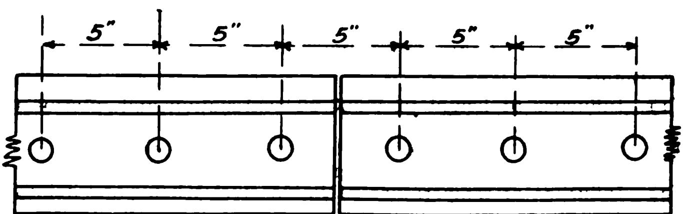
(14) Quantitative influence of carbon on deflection and ductility.
(15) Quantitative influence of phosphorus on deflection and ductility.
(16) Quantitative influence of manganese on deflection and ductility.
(17) Influence of titanium on open-hearth ingots and rails.
(18) Influence of aluminum on open-hearth ingots and rails.
(19) Influence of sulphur in production of seams.

Miscellaneous.

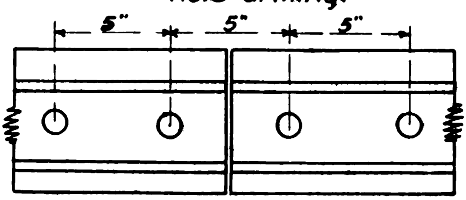
(20) Cause of transverse fissures in rail head.
(21) Investigate electric steel rails.
(22) Influence of low temperature on ductility and other properties of rails.
(23) Influence of heat treatment on the properties of rail steel.
(24) Influence of carbon on resistance under rolling loads.

(4) RAIL JOINTS.

By Circulars Nos. 1347 and 1348 of the A. R. A., information in regard to the length and drilling and the individual preference for four- and six-hole bars on a large number of representative railroads of the country has been obtained. In this Circular a proposed drilling for four- and six-hole bars was submitted for criticism. The replies have been tabulated and are shown in Appendix G. A study of the information shows, for instance, the distance between centers of the middle holes at the joint to vary from 3⅞ to 8½ in., one road using a distance of 3⅞ in. and one road using a distance of 8½ in. It is further found by studying the tables that three distances, 5 in., 5½ in., and 6 in. are used by a large number of companies. The Committee on Track recommended a standard drilling, as follows, which was adopted in 1904 and appeared in the Manual:



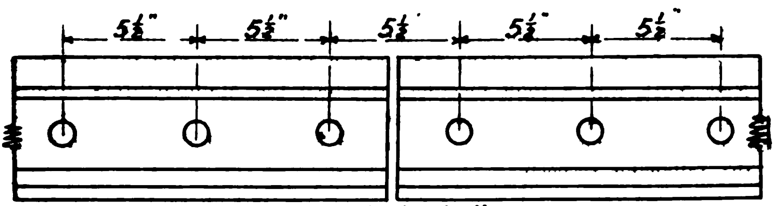
6-hole drilling.



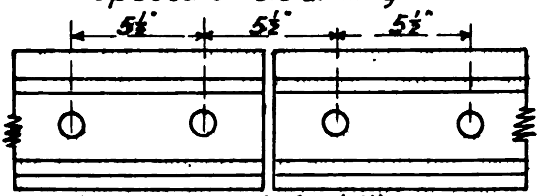
4-hole drilling.

This recommendation was withdrawn.

From the information supplied, the Committee is of the opinion that it would be very difficult to get all the roads to agree to a single standard drilling, for the reason that there is a very great feeling against change of standards. The Committee is of the opinion that this feeling is more or less of a prejudice and has no substantial foundation. It is also the invariable rule when new rail is laid to purchase new angle bars, but by and by, the old standards will disappear and modern standards will take their places in case of changes. After canvassing the matter thoroughly, the Sub-Committee voted in favor of the following drilling:



Proposed 6-hole drilling.



Proposed 4-hole drilling.

A study of the length of bars used shows that for six-hole bars it varies from 26 to 44 in., and for four-hole bars, from 21 to 27 in. It would appear that there is no good reason for variation between the limits of 30 and 36 in. for six-hole bars, and between 24 and 26 in. for four-hole bars.

With the spacing of holes recommended by your Committee, 24 in. is a satisfactory length for four-hole bars, and 32 in. a satisfactory length for six-hole bars, where suspended joints are used.

STRESSES IN RAIL.

The subject of "Stresses to which rails are subjected in service," which was referred to your Committee, has been considered by Sub-Committee D, A. S. Baldwin, Chairman. This Committee reported as follows:

"After considering the subject of rail stresses, the Committee is of the opinion that no material benefit is to be gained by further mathematical investigation and discussion, unless accompanied by actual tests under service conditions, and recommends that the Rail Committee authorize that steps be taken for a series of tests to determine these stresses under varying conditions, and as a means of accomplishing this, it is

suggested that a combination be formed of the Rail Committee with the Roadway, Track and Ballast Committees, for conducting these tests for rails, jointly with the tests proposed to be made by the three last named Committees, through the proposed Joint Committee from the A. S. C. E. and the A. R. E. A."

At the last meeting of the Board of Direction this whole subject was referred to a Joint Committee of those two societies. The Rail Committee will therefore take no futher action on this subject.

REVISION OF SPECIFICATIONS.

There has been considerable discussion between the members of the Rail Committee and members of the Manufacturers' Committee as to some parts of the specifications for Carbon Steel Rails, and the meeting at New York was a joint meeting, at which the Manufacturers' Committee was present, and at which these matters were discussed. As a result of these discussions, your Committee has revised the specifications in the following respects:

EXPLANATION OF CHANGES.

Section 1 of the 1913 specifications has been changed to include section 35, which latter requires the loading of rails to be done in the presence of the inspector. Section 1 of the proposed 1914 specifications now reads: "Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made and *loaded* in accordance with the terms of the specifications."

Under the subject of chemical composition, the carbon limits of open-hearth rails of 85 to 100 lbs. per yard have been changed from .63 to .76 per cent. to .62 to .75 per cent. This was done mostly to conform to the present requirements of the two large systems, the New York Central Lines and the Pennsylvania System.

Section 6 of the 1913 specifications, permitting an increase of carbon for a decrease in phosphorus, has been omitted. The type of rail failure known as "transverse fissure" in the head of the rail seems to occur mostly in rails containing over .80 per cent carbon, and it is thought well for the present to keep the maximum carbon limit below this amount in weights of rails covered by these specifications. Omitting this section changes the numbers of all the succeeding sections.

Section 13 of the 1913 specifications reading, "The test shall, at the option of the inspector, be placed head or base upwards on the supports, etc." has been changed in section 12 of the new specifications to read: "The test piece shall ordinarily be placed head upwards on the supports, etc." The manufacturers complained that the constant reversal of the position of the rail on the supports wore the supporting surfaces and the striking die so that it was difficult to maintain these surfaces in proper condition for making a fair test of the rail.

Section 16 of the 1913 specifications has been revised as section 15 of the new specifications by adding a definition of interior defect as follows: "The words 'interior defect,' used below, shall be interpreted to mean seams, laminations, cavities or interposed foreign matter made visible by the destruction tests, the saws or the drills."

Section 24 of the 1913 specifications deals with the length of rails and allows a variation of ¼ in. from the specified lengths. This part has been revised in secion 23 of the new specifications to read as follows: "A variation of ¼-in. from the specified lengths will be allowed, *excepting that for* 15 *per cent. of the order a variation of ⅜-in. from the specified lengths will be allowed.*" The manufacturers claimed that a variation of not more than ¼-in. on all rails is not practicable, and although this has been the requirement, it has not been strictly enforced by the inspectors.

Section 31 of the 1913 specifications reads, "Circular holes for joint bolts shall be drilled accurately in every respect to the drawing and dimensions furnished by the Railroad Company." This has been amended in section 30 of the proposed 1914 specifications to read as follows: "Circular holes for joint bolts shall be drilled to conform to the drawing and dimensions furnished by the Railroad Company. A variation of 1/32-in. in excess in size of holes will be allowed."

The full text of the specifications as revised will be found in Appendix H.

CONCLUSIONS.

(1) That the revision of the specifications for Carbon Steel Rails, presented herewith, be approved for printing in the Manual.

(2) That form M.W. 408, "Statement of Rail Failures," as revised and presented herewith, be approved for use and substitution in the Manual for the present standard forms M.W. 408 and 411.

Respectfully submitted,

COMMITTEE ON RAIL.

Appendix A.

RAIL FAILURE STATISTICS FOR THE YEAR ENDING OCTOBER 31, 1912.

By R. Trimble,

Chief Engineer, Maintenance of Way, Northwest System, Pennsylvania Lines.

To the Members of the American Railway Engineering Association:

Your Rail Committee submits the following report on Rail Failure Statistics for the year ending October 31, 1912:

At our request the American Railway Association issued Circular No. 1223, dated October 19, 1912, asking the members of that Association for reports to be submitted not later than February 15, 1913. This circular was accompanied by a circular of instructions, in order that the reports might be uniform.

The responses to this circular were more complete and in better form than ever before. Attention should be called, however, to the fact that many roads showed some carelessness in reports, particularly the "Position in Ingot" report. The request for reports prepared so that they could be blueprinted was in many cases disregarded.

Replies were received from 157 companies, 12 of which are Associate Members, and do not make these reports. Of the 145 members replying, 51 do not keep these statistics and 94 furnished reports. Of these reports the majority were in such shape that they could be used without correction. A few had to be returned for correction, and parts of others eliminated, because the data was incomplete.

The 94 companies reporting aggregate a total mileage of about 182,000 miles. The total tonnage of rail covered by the statistics is 14,132,982 tons, of which 10,156,935 tons is Bessemer and 3,580,021 tons Open-Hearth of standard sections; the balance, 396,026 tons, being made up of various alloy and special section rails.

Diagrams and tables as follows are submitted:

(1) Diagram No. 1, Comparison between different *Weights of Rail, Bessemer Steel.*

(2) Diagram No. 2, Comparison between different *Weights of Rail, Open-Hearth Steel.*

(3) Diagram No. 3, Comparison between different *Sections of Rail, Bessemer Steel.*

(4) Diagram No. 4, Comparison between different *Sections of Rail, Open-Hearth Steel.*

(5) Diagram No. 5, Comparison between different *Manufacturers of Rail, Bessemer Steel.*

(6) Diagram No. 6, Comparison between different *Manufacturers of Rail, Open-Hearth Steel.*

(7) Diagram No. 7, Comparison between different *Weights of Rail, Bessemer Steel, for period of 4 years.*

(8) Diagram No. 8, Comparison between different *Weights of Rail, Open-Hearth Steel, for period of 4 years.*

(9) Diagram No. 9, Comparison between different *Weights and Sections, sub-classified by Railroads and Manufacturers, Bessemer Steel Rail.*

(10) Diagram No. 10, Comparison between different *Weights and Sections, sub-classified by Railroads and Manufacturers, Open-Hearth Rail.*

(11) Diagram No. 11, Comparison between different *Railroads, Bessemer Rail.*

(12) Diagram No. 12, Comparison between different *Railroads. Open-Hearth Rail.*

(13) Diagram No. 13, Comparison between different *Railroads, All Rail.*

(14) Table No. 1, Statement of Rails for which no failures were reported. Pages 4 and 5, Bessemer; pp. 5 to 7. Open-Hearth; pp. 7 and 8, Special Sections and Alloys.

(15) Table No. 2, Statement of Rails for which greatest number of failures were reported, arranged in diminishing order, down to 50 per 10,000 tons. Pages 10 to 16, Bessemer Steel; pp. 16 and 17. Open-Hearth Steel; page 17, Special Sections and Alloys.

(16) Table No. 3, Statement of Percentages of different kinds of failures for 4 years.

(17) Table No. 4, Order of Superiority of Various Rail Sections, based on relative number of failures per 10,000 tons.

(18) Table No. 5, Statement of Head Failures per 10,000 tons, for different weights and sections, arranged in diminishing order; page 22. Bessemer; page 23, Open-Hearth; page 24, Alloys.

(19) Table No. 6, Comparisons of failures of rails of same weights and sections, under different conditions.

(20) Table No. 7, Summary of Number of Rail Failures classified according to position in ingot; pp. 30 and 31, Bessemer; pp. 32 and 33, Open-Hearth; page 34, Alloys.

(21) Table No. 8, General Summary of Failures according to position in ingot, arranged according to weight and section.

(22) Table No. 9, General Summary of Failures, according to position in ingot, arranged according to manufacturers.

Drawings of the rail sections referred to will be found in Vol. 12, Proceedings American Railway Engineering Association, Part 2, page 143, et seq.

In all the tables there has been added this year a column giving the tons of rail laid, as it seems important to consider this as well as the failures per 10,000 tons.

TABLE NO. 1—LIST OF VARIOUS LOTS OF RAIL FOR WHICH NO FAILURES WERE REPORTED.

In this list we find rail of practically all weights and sections, and of the following manufacture:

Bessemer Steel: Algoma, Cambria, Carnegie, Illinois, Lackawanna, Maryland, National, Ougree, Pennsylvania.

Open-Hearth Steel: Bethlehem, Cambria, Carnegie, Colorado Fuel & Iron, Illinois, Lackawanna, Maryland, Pennsylvania, Tennessee Coal & Iron.

The chemistry varies widely, as does the length of service. The oldest rail listed is 100 lbs., P. R. R., rolled by Lackawanna Steel Company, 1893 to 1907—269 tons laid; of this 205 tons were laid in 1900. Much of the rail is of comparatively short service.

Note.—All amounts reported under 1,000 tons neglected in making this report, excepting in the case of special sections and alloys.

TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES

Weight per Yard	Section	Tons Laid	Manufacturer	Year	Specified Chemical Composition C.	P.	Mn.	Si.	S.	Railroad
				BESSEMER STEEL						
100	A. S. C. E.	1439	Cambria	1904	.50	.08	1.00	.13	......	Penna. Lines, N. W. System
100	N. Y. N. H. & H.	3153	Lackawanna	1905	.50 .60	 .10	.08 1.10	 .20	......	New York, New Haven & Hartford
90	A. R. A. "B"	38388	Illinois	1911–1912	......	......	......	......	......	Chicago & Northwestern
90	A. S. C. E.	1575	Penna.	1898	......	......	......	......	......	Long Island
90	G. N.	1134	Algoma	1909	.45 .55	.10	.80 1.10	.20	......	Great Northern
85	A. S. C. E.	100000	Lackawanna	1907	.48 .58	.10	.80 1.10	.20	......	Atlantic Coast Line
85	A. S. C. E.	3463	Maryland	1901–1903	.40 .60	.07	1.00 1.20	......	......	Long Island
85	A. S. C. E.	12830	Carnegie	1903	.43 .53	.10	.80 1.10	.20	......	Missouri, Kansas & Texas
85	A. S. C. E.	20811	Illinois	1905–1909	.43 .53	.10	.80 1.10	.20	......	Missouri, Kansas & Texas
85	A. S. C. E.	1090	Illinois	1903–1906	.48 .58	.10	.80 1.10	.20	......	Toledo, Peoria & Western
85	P. R. R.	2501	Maryland	1910–1912	.448 .480	.051 .064	.95 1.00	.054 .072	.054 .067	Baltimore, Chesapeake & Atlantic
85	O. W. R. & N.	4324	Illinois	1899–1900	......	......	......	......	......	Oregon-Washington R. & N. Co.
80	A. R. A. "A"	1774	Illinois	1909–1911	.40 .50	.10	.75 1.05	.20	......	Toledo, Peoria & Western
80	A. R. A. "A"	2414	Lackawanna	1909	.40 .50	.10	.75 1.05	.20	......	Minne. St. Paul & Sault Ste. Marie
80	A. S. C. E.	3600	Illinois	1911	.40 .50	.10	.75 1.05	.20	......	Cincinnati Northern
80	A. S. C. E.	3614	Lackawanna	1897–1905	......	......	......	......	......	Delaware & Hudson
80	A. S. C. E.	1600	Illinois	1905	.55	.085	.90	.20	.075	Galveston, Harrisburg & San Antonio
80	A. S. C. E.	5149	Algoma	1902	.43 .53	.10	.80 1.10	.10 .20	.07	Michigan Central
80	A. S. C. E.	3480	Lackawanna	1907–1910	.48	.10	1.00	.20	......	Munising, Marquette & South Eastern
80	A. S. C. E.	1985	Illinois	1896–1904	.48	.09	.92	.094	......	Munising, Marquette & South Eastern
80	A. S. C. E.	1108	Lackawanna	1906–1910	.48	.10	1.00	.20	......	Munising, Marquette & South Eastern
80	A. S. C. E.	1402	Carnegie	1905	.44 .52	.090 .095	.85 .95	.060 .075	......	Rock Island

80	A. S. C. E.	8964	Carnegie	1902-1903	.55	.085	.90	.20	.075	......	Texas & New Orleans
80	A. S. C. E.	4000	Illinois	1902	.55	.085	.90	.20	.075	......	Texas & New Orleans
80	Dudley	14728	Maryland	1900	......	......	......	......	......	......	Seaboard Air Line
75	A. S. C. E.	1425	Cambria	1906-1907	......	......	......	......	......	......	Louisiana & Arkansas
75	A. S. C. E.	11754	Illinois	1902-1912	......	......	......	......	......	......	Louisiana & Arkansas
75	A. S. C. E.	6276	National	1901	.40 .50	.10	.75 1.05	.20	......	......	St. Louis, San Francisco & Texas
75	A. S. C. E.	1802	Cambria	1905	.48 .55	.10	.80 1.10	.20	......	......	Southern
75	B. & M.	20273	Lackawanna	1904-1906	.43 .53	.10	.80 1.10	.20	......	......	Boston & Maine

OPEN-HEARTH

100	A. R. A. "A"	1050	Cambria	1912	.70 .80	.04	.75 1.00	.05 .20	......	......	Baltimore & Ohio
100	A. R. A. "A"	2019	Maryland	1910	.62 .75	.04	.60 .90	.20	......	......	Central of New Jersey
100	A. R. A. "B"	3800	Bethlehem	1912	.62 .75	.04	.80	.05 .20	.04	......	Norfolk & Western
100	A. R. A. "B"	1097	Cambria	1912	.62 .75	.04	.80	.05 .20	.04	......	Norfolk & Western
100	A. R. A. "B"	2175	Penna	1912	.62 .75	.04	.80	.05 .20	.04	......	Norfolk & Western
100	A. R. A. "B"	3108	Col. F. & I.	1912	.60 .70	.06	.70 1.00	.20	......	......	Northern Pacific
100	A. R. A. "B"	2048	Penna	1912	.62 .75	.04	.60 .90	.20	......	......	Northern Pacific
100	A. S. C. E.	5000	Illinois	1912	.64 .77	.04	.70 1.00	.20	......	......	Chicago, Burlington & Quincy
90	A. R. A. "A"	3497	Illinois	1912	.64	.083	.710	.16	......	......	Chicago & Eastern Illinois
90	A. R. A. "A"	4530	Tenn. C. & I.	1910-1912	.63 .76	.04	.70 1.00	.20	......	......	Louisiana Western
90	A. R. A. "B"	1000	Cambria	1912	.63 .76	.04	.60 .90	.20	......	......	Chicago, Indianapolis & Louisville
90	A. R. A. "B"	6000	Illinois	1912	.63 .76	.04	.60 .90	.20	......	......	Chicago, Indianapolis & Louisville
90	A. R. A. "B"	4837	Col. F. & I.	1912	.58 .68	.06	.70 1.00	.20	......	......	Northern Pacific
90	A. S. C. E.	5040	Carnegie	1911	.70 .85	.03	.60 .90	.20	......	......	Philadelphia & Reading
90	A. S. C. E.	2185	Tenn. C. & I.	1912	.59 .72	.04	.60 .90	.20	......	......	St. Louis & San Francisco

TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES—CONTINUED.

Weight per Yard	Section	Tons Laid	Manufacturer	Year	Specified Chemical Composition					Railroad
					C.	P.	Mn.	Si.	S.	
				OPEN-HEARTH—Continued						
85	A. S. C. E.	5090	Penna.	1912	.55 .68	.06	.60 .90	.20		Atlantic Coast Line
85	A. S. C. E.	3236	Illinois	1911-1912	.58 .71	.054	.70 1.00	.10 .20		Indiana Harbor Belt
85	A. S. C. E.	5000	Bethlehem Maryland	1912	.72	.04	.75	.20		Maine Central
85	A. S. C. E.	1623	Bethlehem	1912	.59 .72	.04	.60 .90	.20		Southern
85	Dudley	1404	Tenn. C. & I.	1911	.59 .72	.04	.60 .90	.20		Seaboard Air Line
85	P. S.	1000	Cambria	1910	.62 .75	.04	.80	.05 .20		G. R. & I. (Northern Division)
80	A. R. A. "A"	14587	Illinois	1911	.52 .65	.04	.60 .90	.20		Minneapolis, St. Paul & Sault Ste. Marie
80	A. S. C. E.	1432	Illinois	1912	.65 .80	.04	.75 1.00	.05 .20		B. & O. Chicago Terminal
80	A. S. C. E.	1230	Col. F. & I.	1909	.65	.06	1.00	.20		Colorado Midland
80	A. S. C. E.	2800	Col. F. & I.	1901						Galveston, Harrisburgh & San Antonio
80	A. S. C. E.	7252	Illinois	1912	.55 .68	.04	.70 1.00	.10 .20		Lake Shore & Michigan Southern
80	A. S. C. E.	6338	Tenn. C. & I.	1902-1904	.55	.085	.90	.20	.075	Texas & New Orleans
80	A. S. C. E.	3750	Illinois	1912	.66	.04	.85	.15		Toledo & Ohio Central
75	A. S. C. E.	5280	Tenn. C. & I.	1910-1912	.55 .60	.04	.70 1.00	.20		Illinois Central
75	C. S.	1048	Col. F. & I.	1910-1911	.55	.085	.80 1.10	.20	.075	Arizona Eastern
75	C. S.	2463	Col. F. & I.	1911-1912	.45 .63	.085	.75 1.00	.20		Houston & Texas Central
75	C. S.	1541	Tenn. C. & I.	1908-1912	.50 .60	.085	.80 1.10	.20	.075	Houston East & West Texas
75	C. S.	1884	Col. F. & I.	1910-1912	.55 .68	.04	.70 1.00	.20		Texas & New Orleans
75	C. S.	2234	Tenn. C. & I.	1912	.55 .68	.04	.70 1.00	.20		Morgan's Louis. & Texas
75	C. S.	3750	Illinois	1912	.66	.04	.85	.15		Toledo & Ohio Central
75	Dudley	4672	Bethlehem	1911	.55 .68	.04	.60 .90	.20		Seaboard Air Line

72	N. P.	1172	Cambria	1912	.52 .65	.04	.60 .90	.20	......	......	Northern Pacific
72	N. P.	3110	Illinois	1912	.52 .65	.04	.60 .90	.20	......	......	Northern Pacific.
72	N. P.	3404	Lackawanna	1912	.52 .65	.04	.60 .90	.20	......	......	Northern Pacific
72	N. P.	1757	Penna.	1912	.52 .65	.04	.60 .90	.20	......	......	Northern Pacific
				SPECIAL SECTIONS OR STEELS—BESSEMER							
141	Girder	2616	Penna.	1905–1912	.50	.08	1.00	.13	......	......	Penna. Lines, East
85	Girder	162	Penna.	1902–1906	.50	.08	1.00	.13	......	......	Penna. Lines, East
				Ferro-Titanium						F. T.	
100	A. R. A. "A"	1282	Lackawanna	1912	.45 .55	.10	.84	.84 1.10	......	.10	Chicago & Eastern Illinois
100	A. R. A. "A"	480	Lackawanna	1911	.45 .55	.10	.84 1.14	.20	......	......	Rock Island
90	A. R. A. "B"	260	Illinois	1912	.45 .55	.10	.70 1.00	.05 .20	......	.10	Northern Pacific
90	A. S. C. E.	839	Lackawanna	1912	.43 .53	.10	.80 1.10	.20	......	......	St. Louis & San Francisco
85	A. S. C. E.	300	Lackawanna	1910	.48 .58	.10	.80 1.10	.20	......	.30	Atlantic Coast Line
85	A. S. C. E.	500	Lackawanna	1910	.43 .53	.10	.80 1.10	.13 .20	......	......	Chicago Great Western
85	A. S. C. E.	18899	Illinois	1910–1911	.43 .53	.10	.80 1.10	.15 .20	......	.30	Missouri, Kansas & Texas
80	A. S. C. E.	521	Lackawanna	1910–1912	.40 .50	.10	.75 1.05	.20	......	.30	Munising, Marquette & South Eastern
				Mayari—Chrome Nickel					Chro.	Ni.	
100	N. Y. N. H. & H.	4571	Maryland	1911	.45 .55	.07	.82 1.08	.20	.23 .38	.50 .90	New York, New Haven & Hartford
100	P. S.	3800	Maryland	1912	.45 .55	.06	.80 1.05	.20	.20 .35	.75 .90	Penna. Lines-N. W. System
100	P. S.	30	Maryland	1912	.45 .55	.06	.80 1.05	.20	.20 .35	.75 .90	Penna. Lines-S. W. System
85	A. S. C. E.	3370	Maryland	1912	......	......	......	......	......	......	Southern
85	A. S. C. E.	30700	Maryland	1911–1912	.40 .50	.075	.85 1.20	.20	.20 .55	.20 .90	Missouri, Kansas & Texas

TABLE No. 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES—CONTINUED.

Weight per Yard	Section	Tons Laid	Manufacturer	Year	Specified Chemical Composition C	P.	Mn.	Si.	S.		Railroad
	SPECIAL SECTIONS OR STEELS—OPEN-HEARTH										
	High Silicon										
100	P. S.	51	Illinois	1911	.725	.029	.80	.31	......	......	Penna. Lines-N. W. System
	Ferro-Titanium										
100	A. R. A. "B"	229	Maryland	1911	.70 .80	.10	.80 1.20	.05 .20	......	F. T. .10	Baltimore & Ohio
	Electric Process										
100	A. R. A. "A"	287	Illinois	1911-1912	.50 .65	.07	.50 .80	.10 .18	......	......	Rock Island
100	P. S.	196	Illinois	1912	.57 .70	.04	.50 .80	.15 .25	......	......	Penna. Lines-S. W. System
100	P. S.	800	Illinois	1912	.57 .70	.04	.50 .80	.15 .25	......	......	Penna. Lines-N. W. System
90	A. R. A. "B"	340	Illinois	1912	.50 .65	.06	.50 .80	.10 .18	......	......	Northern Pacific
	Mayari—Chrome Nickel										
									Chro.	Ni.	
100	N. Y. N. H. & H.	333	Maryland	1910-1911	.60 .74	.04	.60 .90	.20	.30 .45	.50 .72	New York, New Haven & Hartford
100	D. L. & W.	240	Penna.	1911	.778	.014	.75	.07	.12	1.63	Delaware, Lackawanna & Western

TABLE NO. 2—LIST OF LARGEST NUMBER OF FAILURES ARRANGED IN DIMINISHING ORDER DOWN TO 50 FOR CONVENIENCE IN STUDYING COMPOSITION.

Table No. 1 should be considered in connection with table No. 2.

In last year's report this table was not classified with respect to kind of steel. This year separate statements are made for the Bessemer. Open-Hearth and Special Alloys. The same remarks as were made last year apply this, i. e., this table shows—

(1) Wide variation in performance of different sections.

(2) Wide variation in performance of different mills.

(3) Same weights and sections do not give uniform results.

(4) Difference in carbon does not account for variation in rate of failure.

(5) Comparison of Open-Hearth and Bessemer shows that both have high rates of failure as well as low rates in individual cases.

(6) The so-called improved sections, such as A. R. A., give poor results in individual cases, while the older sections, such as the A. S. C. E., give good results in some cases.

(7) It is also to be noted that much of the rail listed in table No. 2 has been in service a short time.

In addition to the above remarks, attention should be called to the fact that there are 140 items on the Bessemer list and 25 on the Open-Hearth, a ratio of about 5½ to 1, while the ratio of the tonnage of Bessemer to Open-Hearth is about 3 to 1. Also that the greatest number of failures per 10,000 tons of Open-Hearth rail is 378.5, while that of the Bessemer is 1,050.0. Also that in only 9 cases of Open-Hearth is the rate of failures above 100, while in the Bessemer there are 50 cases.

Note.—All amounts reported under 1,000 tons neglected in making this report, excepting in the case of Special Sections and Alloys.

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES.

	No. Failures per 10,000 Tons	Tons Laid	Wt.	Section	Manufacturer	Year	Specified Chemical Composition C.	P.	Mn.	Si.	S.	Predominant Failures	Railroad
							BESSEMER RAIL						
1	1050	3230	85	A. S. C. E.	Illinois	1902-07	.47	.098	.85	.099	......	Broken	Baltimore & Ohio
2	722	4958	75	A. S. C. E.	Lackawanna	1907	.45 .55	.10	.75 1.05	.20	......	Broken	Chicago, Indianapolis & Louisville
3	673	5527	85	A. S. C. E.	Carnegie	1906-08	.48 .58	.10	.80 1.10	.20	......	Broken	Northern Pacific
4	617	18184	90	A. S. C. E.	Illinois	1906-11	.48 .58	.10	.80 1.14	.20	.075	Broken Broken	Erie Cleveland, Cincinnati, Chicago & St. Louis
5	577	5250	90	A. S. C. E.	Lackawanna	1906	.50 .60	.10	.80 1.10	.20	......	Broken Base	
6	468	14578	90	G. N.	Lackawanna	1908-09	.48	.10	.95	.20	......	Broken Base	Great Northern
7	412	4500	85	A. S. C. E.	Lorain	1906	.48 .58	.10	.80 1.10	.20	......	Broken	Northern Pacific
8	364	1535	100	A. R. A. "A"	Carnegie	1909	.50	.10	1.00	.12	......	Head Failures	Penna. Lines—S. W. System
9	335	2000	100	A. S. C. E.	Illinois	1907	.48 .58	.10	.80 1.10	.20	......	Broken 30%, Broken Base 30%, Head Failure 40%	Chicago, Burlington & Quincy
10	331	2598	90	C. S.	Illinois	1906	.50 .60	.10	.80 1.10	.20	......	Broken, Head Failures	Oregon Short Line
11	294	6829	90	A. R. A. "A"	Carnegie	1909-11	.50	.10	1.00	.125	......	Broken 53%, Head Failures 39%	Baltimore & Ohio
12	271	41439	100	A. S. C.E.	Lackawanna	1905-10	.54	.10	.95	.15	......	Broken 41%, Head Failure 25%, Broken Base 33%	Lake Shore & Michigan So.
13	268	6156	80	A. S. C. E.	Lackawanna	1904-12	.40 .58	.075 .105	1.00	.20	......	Head Failures	Central Vermont
14	262	15457	90	A. R. A. "A"	Illinois	1908-11	.50	.10	1.00	.15	.075	Broken	Baltimore & Ohio
15	241	5596	85	Mo. P.	Illinois	1905-11	......	......	......	......	......	Broken	Cincinnati, Hamilton & Dayton
16	215	49291	85	A. S. C. E.	Lackawanna	1906-09	.43 .58	.10	.80 1.10	.20	......	Broken	Northern Pacific
17	208	7474	80	A. S. C. E.	Carnegie	1904-05	.50 .60	.085	.80 1.10	.20	.075	......	Union Pacific
18	195	157546	85	A. S. C. E.	Illinois	1903-09	.43 .58	.10	.80 1.10	.20	......	Broken, Broken Base	Northern Pacific
19	191	36085	90	A. R. A. "B"	Carnegie	1908-11	.50	.10	1.00	.125	.075	Head Failures	Baltimore & Ohio
20	189	84435	90	A. S. C. E.	Illinois	1906-10	.50 .60	.10	.80 1.00	.20	......	Broken, Broken Base	Cleveland, Cincinnati, Chicago & St. Louis

21	186	78445	90	A. S. C. E...	Carnegie	1900-11	.45 .55	.10	.80 1.15	.20	.075	......	Broken 40%, Head Failures 55.......	Erie
22	183	18282	80	A. S. C. E...	Illinois......	1886-11	.45 .55	.10	.80 1.20	.05 .20	......	......	Broken...............	B. & O., Chicago Terminal
23	170	3807	90	A. S. C. E...	Carnegie..	1900-10	.47 .57	.10	.82 1.10	.20	.075	......	Broken 35% Head Failures 60%.......	Pittsburgh & Lake Erie
24	164	25056	90	C. S.........	Carnegie....	1906-11	.50 .60	.10	.80 1.10	.20	.075	......	Head Failures.........	Union Pacific
25	162	3511	80	A. S. C. E...	Lackawanna.	1904	.50 .60	.085	.80 1.10	.20	.075	......	Broken 50%, Head Failures 50%.........	Union Pacific
26	160	7712	90	A. R. A. "B"	Cambria...	1909-11	.50	.10	1.00	.125	.075	......	Head Failures.........	Baltimore & Ohio
27	147	17190	85	P. S.........	Carnegie....	1909-12	.50	.10	1.00	.12	......	......	Head Failures.........	Penna Lines, N. W. System
28	146	148210	85	A. S. C. E...	Illinois......	1905-10	.43 .55	.088 .10	.80 1.10	.06 .20	......	......	Broken...............	Rock Island
29	145	1100	85	A. S. C. E...	Carnegie...	1909	.45 .53	.10	.80 1.10	.20	......	......	Broken...............	Minneapolis, St. Paul & Sault St. Marie
30	142	5840	85	Mo. P.......	Lackawanna.	1905	......	......	......	......	......	......	Broken...............	Cincinnati, Hamilton & Dayton
31	140	27400	90	A. S. C. E...	Carnegie....	1905-10	.50 .60	.10	.80 1.10	.20	......	......	Broken...............	Cleveland, Cincinnati, Chicago & St. Louis
32	139	1786	85	A. S. C. E...	Carnegie....	1899	.43 .53	.10	.80 1.10	.20	......	......	Head Failures.........	Boston & Maine
33	129	7720	80	A. S. C. E...	Cambria....	1902-05	.50	.10	.96	1.08	.05	......	Broken	Hocking Valley
34	127	4162	85	P. R. R......	Illinois......	1897-98	......	......	......	......	......	......	Head Failures.........	Vandalia
35	124	2178	100	A. R. A. "B"	Cambria....	1910-11	.51	.10	1.00	.125	......	......	Head Failures.........	Baltimore & Ohio
36	124	14836	80	Dudley......	Carnegie....	1906-10	.50	.10	1.00	.15	.05	......	Head Failures.........	Toledo & Ohio Central
37	123	4500	80	Dudley......	Lackawanna.	1906-09	.43 .58	.10	.80 1.10	.13 .20	.075	......	Broken Base 64%, Split Web 36%...........	Rutland
38	119	5607	90	A. S. C. E...	Carnegie....	1908	.45 .55	.10	.85 1.15	.20	.075	......	Head Failures.........	Erie & Jersey
39	118	9076	80	A. S. C. E...	Lackawanna.	1904-07	.40 .50	.10	.75 1.05	.20	......	......	Broken, Broken Base..	Minneapolis, St. Paul & Sault St. Marie
40	115	12785	85	A. S. C. E...	Cambria....	1903-06	.40 .55	.10	1.20	......	......	......	Broken, Broken Base..	Grand Rapids & Indiana
41	114	122080	100	A. S. C. E...	Illinois......	1905-10	.52	.10	.96	.14	......	......	Broken 50%, Broken Base 20%, Head Failures 33%............	Lake Shore & Michigan Southern
42	113	34237	85	A. S. C. E...	Lackawanna.	1904-08	.43 .53	.10	.80 1.10	.20	......	......	Broken, Broken Base..	Boston & Maine
43	112	22228	100	A. S. C. E...	Carnegie.	1901-07	.40 .55	07	1.20	......	......	......	Broken, Head Failures	Penna. Lines, N. W. System
44	107	33650	90	C. S.........	Illinois......	1906-12	.50 .60	.10	.80 1.10	.20	.075	......	Broken...............	Union Pacific
45	106	20790	80	A. C. S. E...	Carnegie.	1900-08	......	......	......	......	......	......	Broken 33%, Head Failures 45%, Broken Base 16%...........	Central Vermont

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,00 Tons	Tons Laid	Wt.	Section	Manufacturer	Year	Specified Chemical Composition C.	P.	Mn.	Si.	S.	Predominant Failures	Railroad
							BESSEMER RAIL—Continued						
46	105 8	16066	90	A. S. C. E.	Carnegie	1906-09	.50	.10	.98	1.03	.05	Broken	Hocking Valley
							.48			.16			
47	105 2	38922	85	A. S. C. E.	Lackawanna	1906-10	.53	.10	.95	.20	.075	Broken	Maine Central.
							.48		.80	.10			
48	105	18541	85	A. S. C. E.	Carnegie	1908	.58	.10	1.10	.20	.075	Head Failures	Carolina, Clinchfield & Ohio
							.48		.80	.10		Broken, 19%, Broken	
49	103 5	65000	85	C. B. & Q.	Illinois	1907-08	.58	.10	1.10	.20	.075	Base 44%, Head Fail-	
												ures 36%.	Chicago, Burlington & Quincy
							.48		.80			Broken 35%, Head Fail-	
50	102.0	5296	90	A. S. C. E.	Lackawanna	1906-08	.58	.10	1.15	.20	.075	ures 60%.	Erie & Jersey
51	98.7	2338	85	P. S.	Illinois	1909-11	.50	.10	1.00	.12		Broken, Broken Base	Penna. Lines—N. W. System
							.43		.80	.06			
52	96.7	15105	85	A. S. C. E.	Carnegie	1905-09	.53	.10	1 10	.20		Broken	Chicago & Eastern Illinois
							.49		.90			Broken 32%, Broken	
53	96 2	55391	100	A. S. C. E.	Lackawanna	1903-10	.56	.10	1.10	.20		Base 16%, Head Fail-	
												ures 51%	Michigan Central
54	96 0	177202	90	A. S. C. E.	Illinois	1898-11						Broken	Chicago & North-Western
							.48		.89	.10			San Pedro, Los Angeles &
55	94.7	9184	75	A. S. C. E.	Ougree	1901-05	.58	.085	1.00	.15	.05	Head Failures	Salt Lake
56	93.2	20600	100	A. S. C. E.	Maryland	1905-08	.51	.078	.96	.06	.075	Head Failures	Baltimore & Ohio
							.40					Broken 33%, Broken	
57	93 0	170439	85	A. S. C. E.	Carnegie	1899-07	.55	.07	1.20			Base 16%, Head Fail-	
												ures 44%	Penna Lines—N. W. System
58	92.6	143035	85	A. S. C. E.	Carnegie	1908-08	.50	.09	.95	.20	.05	Broken	Baltimore & Ohio
59	92.6	17713	85	A. S. C. E.	Lackawanna	1898-01						Broken	Boston & Maine
60	92.2	28112	90	A. S. C. E.	Carnegie	1903-09						Broken Base	Lehigh Valley
61	92 0	2500	100	P. S.	Cambria	1908-12	.50	.10	1.00	.12		Head Failures	Penna Lines—S. W. System
62	91.7	1308	75	A. S. C. E.	Cambria	1899						Broken	Alabama Great Southern
63	91.4	5137	80	A. S. C. E.	National	1902						Broken 43%, Head Fail-	
												ures 43%	Grand Trunk
							.43		.75				
64	91.0	7248	80	A. S. C. E.	Lackawanna	1906-10	.55	.10	1.10	.20	.075	Head Failures	Erie
							.48		.80			Broken 36%, Broken	
65	90 7	13562	80	A. S. C. E.	Lackawanna	1904-07	.58	.10	1.10	.20		Base 16%, Head Fail-	
												ures 44%	Grand Trunk
66	90 3	6314	75	B. & M.	Penna	1897-09						Broken	Boston & Maine

67	90 0	2000	90	A. R. A. "B"	Illinois	1909	.50	.10	1.00	.125			Broken, Head Failures	Baltimore & Ohio
							.45		.80	.05				
68	90 0	11010	85	A. S. C. E.	Carnegie	1901-07	.55	.10	1.20	.20			Head Failures	Vandalia
							.43		.80					
69	89.6	10927	90	G. N.	Illinois	1908	.53	.10	1.10	.20			Head Failures	Great Northern
70	89.5	2121	100	A. R. A. "A"	Carnegie	1909	.51	.10	1.00	.125			Head Failures	Baltimore & Ohio
							.44		.82					
71	89 5	15190	80	A. S. C. E.	Carnegie	1901-10	.54	.10	1.10	.20	.075		Head Failures	Pittsburgh & Lake Erie
72	88.8	1238	90	C. S.	Carnegie	1906-07	.60	.085	.90	.20	.075		Head Failures	Galveston, Harrisburg & San Antonio
							.40		.70					
73	88.7	12401	75	A. S. C. E.	Carnegie	1896-07	.55	.10	1.05	.20	.05		Head Failures	St. Louis & San Francisco
					Penna		.65		.70					
74	88.5	8474	80	A. S. C. E.	Maryland	1904-08	.80	.08	1.00	.20			Head Failures	Lehigh & Hudson River
							.45		.80					
75	87.5	6398	90	A. S. C. E.	Cambria	1903-09	.55	.10	1.20	.20			Broken Base	Lehigh Valley
							.43		.80					
76	86.8	71474	85	A. S. C. E.	Illinois	1900-09	.53	.10	1.10	.20			Broken	Minneapolis, St. Paul & S. S. Marie
							.50		.80					
77	84.7	9575	100	A. S. C. E.	Carnegie	1905-06	.60	.10	1.10	.20			Broken, Broken Base	Lake Shore & Michigan Southern
							.48		.80					
78	84 7	6138	100	A. S. C. E.	Lackawanna	1907	.58	.10	1.10	.20			Broken Base	Grand Trunk
79	81.5	19196	100	A. R. A "B"	Maryland	1909-11	.51	.10	1.00	.125			Head Failures	Baltimore & Ohio
							.45		.80	.05				
80	81 0	2962	85	A. S. C. E.	Illinois	1900-05	.55	.10	1.20	.20			Broken	Vandalia
							.40		.75					
81	80.6	6570	75	A. S. C. E.	Carnegie	1894-07	.50	.10	1.05	.20			Broken, Head Failures	Illinois Central
							.40		.70					
82	79.6	11803	75	A. S. C. E.	Carnegie	1895-08	.50	.10	1.05	.20	.05		Broken	Chicago, Indianapolis & St. Louis
83	79.3	27104	75	C. S.	Carnegie	1899-07	.45	.107	.74	.091	.041		Head Failures	Galveston, Harrisburg & San Antonio
							.45	.08	.70					
84	78.0	13068	75	A. S. C. E.	Lackawanna	1907-10	.55	.10	1.00	.20			Broken Base	San Pedro, Los Angeles & Salt Lake
85	77.8	36629	85	P. S.	Carnegie	1909-12	.50	.10	1.00	.12			Head Failures	Penna Lines—S. W. System
86	76.4	16343	75	B. & M.	Maryland	1892-09							Broken, Broken Base	Boston & Maine
							.46		.84					
87	75.4	47885	100	A. S. C. E.	Illinois	1905-09	.56	.10	1.10	.20			Broken	Michigan Central
							.40							
88	74.9	10677	85	A. S. C. E.	Cambria	1900-06	.55	.07	1.20				Broken, Broken Base	Penna. Lines—N. W. System
							.45		.90					
89	74.7	33579	75	B. & M.	Lackawanna	1896-05	.46	.10	.92	.20			Broken, Head Failures	Maine Central
90	73.6	20515	85	P. S.	Illinois	1909-12	.50	.10	1.00	.12			Broken	Penna. Lines—S. W. System
							.43		.80					
91	73.0	4210	90	A. R. A. "B"	Illinois	1911	.53	.10	1.10	.20			Broken	Chicago, Indianapolis & Louisville
92	72.9	1921	100	P. S.	Illinois	1911-12	.50	.10	1.00	.12			Broken	Penna Lines—S. W. System
							.40		.75					
93	72.6	2890	75	"1889"	Illinois	1890-94	.50	.10	1.05	.20			Broken	Illinois Central

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,000 Tons	Tons Laid	Wt.	Section	Manufacturer	Year	Specified Chemical Composition C.	P.	Mn.	Si.	S.		Predominant Failures	Railroad
							BESSEMER RAIL—Continued							
94	71.2	5058	85	A. S. C. E.	Lorain	1905-06	.48 .58	.10	.80 1.10	.20			Broken	Rock Island
95	71.0	27886	75	A. S. C. E.	Illinois	1901-09	.40 .55	.10	.75 1.05	.20			Broken	Chicago, Indianapolis & Louisville
96	70.9	9583	90	G. N.	Cambria	1908	.43 .53	.10	.80 1.10	.20			Head Failures	Great Northern
97	70.9	10006	75	A. S. C. E.	Illinois	1899-07							Broken, Head Failures	Chicago & Indiana Southern
98	70.0	73493	85	P. R. R.	Lackawanna	1887-12	.50	.08	1.00	13			Broken Base 35%. Broken 22%, Head Failures 33%	Penna Lines—East
99	70.0	6141	80	Camb. 540	Carnegie	1902-05	.50	.10	1.00	.15			Head Failures	Toledo & Ohio Central
100	69.8	4584	85	A. S. C. E.	Republic	1905	.40 .55	.07	1.20				Head Failures, Broken Base	Penna Lines—N. W. System
101	69.8	11550	80	A. S. C. E.	Lackawanna	1904-05							Head Failures	Cleveland, Cincinnati, Chicago & St. Louis
102	69.0	14516	85	A. S. C. E.	Illinois	1909-12	.43 .53	.10	1.00	.20			Broken	Chicago & Eastern Illinois
103	68.8	10020	90	C. S.	Illinois	1908-12	.55 .65	.085	.80 1.05	.20			Broken, Head Failures.	Illinois Central
104	68.3	7613	80	A. S. C. E.	Carnegie	1904	.55	.085	.80 1.10	.20			Head Failures	Oregon Short Line
105	68.1	25100	75	B. & M.	Lackawanna	1895-01							Head Failures	Boston & Maine
106	67.6	23493	90	A. S. C. E.	Maryland	1906-10	.53 .57	.10	.40 .60				Broken	Delaware & Hudson
107	66.4	54222	80	A. S. C. E.	Illinois	1899-07	.46 .56	.094	.80 1.10	.20			Broken	Union Pacific
108	65.7	7906	100	A. R. A. "A"	Illinois	1910-11							Head Failures	Chicago & Alton
109	65.5	12366	75	B. & M.	Maryland	1897-03	.45 .55	.085 10	.90 1.20	.20			Broken	Maine Central
110	63.6	64437	80	A. S. C. E.	Col. F. & I.	1901-08	.49 .57	.097	.80 1.10	.10 .20			Broken	Union Pacific
111	63.0	2204	90	A. S. C. E.	Cambria	1907	.54 .64	.10	.90 1.15	.20			Head Failures	Central of New Jersey
112	62.9	64868	100	A. S. C. E.	Carnegie	1896-09	.45 .60						Head Failures, Broken	Bessemer & Lake Erie
113	62.9	31919	80	A. S. C. E.	Col. F. & I.	1901-06	.45 .60	.085 .10	.80 1.16	.10 .20	.075		Head Failures, Broken	Oregon Short Line
114	62.8	25134	85	A. S. C. E.	Lackawanna	1904	.48 .50	10	.80 1.10	20			Head Failures	Atchison, Topeka & Santa Fe

115	62.7	15780	90	A. R. A. "B"	Carnegie	1909-12	.45 .55	.10	.80 1.20	.05 .20			Head Failures	Northern Pacific
116	62.4	48370	100	A. S. C. E.	Algoma	1905-10	.47 .58	.10	.90 1.17	.20			Broken	Michigan Central
117	62.4	40306	85	A. S. C. E.	Maryland	1904-09	.52 .65	.07 .085	.94 1.05	.04 .20			Head Failures	Atchison, Topeka & Santa Fe
118	61.5	67968	90	A. S. C. E.	Lackawanna	1901-10	.45 .55	.10	.80 1.20	.20			Broken Base	Lehigh Valley
119	61.3	5637	90	C. S.	Lorain	1906-07	.50 .60	.10	.80 1.10	.20			Broken	Union Pacific
120	60.9	13472	80	A. S. C. E.	Carnegie / National	1902	.43 .53	.10	.80 1.10	.20			Head Failures	Michigan Central
121	60.5	19488	100	A. R. A. "B"	Carnegie	1908-12	.50 .60						Head Failures, Broken	Bessemer & Lake Erie
122	59.5	107150	80	A. S. C. E.	Carnegie	1890-03	.43 .58	.10	.80 1.10	.20			Head Failures	Cleveland, Cincinnati, Chicago & St. Louis
123	59.3	24810	75	C. S.	Illinois	1907-12	.45 .55	.10	.75 1.00	.20			Broken	Union Pacific
124	58.8	12246	85	A. S. C. E.	Illinois	1899-04	.40 .55	.07	1.20				Broken, Broken Base	Penna. Lines—N. W. System
125	58.4	1541	76	A. S. C. E.	Maryland	1897							Broken, Broken Base	Boston & Maine
126	57.8	78077	85	A. S C. E.	Illinois	1904-07	.48 .63	.09 .10	.90 1.10	.10 .20			Broken, Broken Base	Atchison, Topeka & Santa Fe
127	57.1	8400	80	A. S. C. E.	Carnegie	1903	.43 .53	.10	.80 1.10	.20			Head Failures	Michigan Central
128	56.9	4393	85	P. R. R.	Maryland	1899-02	.50		1.00	.12			Head Failures	Cumberland Valley
129	56.7	12687	80	A. S. C. E.	Dominion	1905	.50 .60	.06	1.10 1.30	.15 .20	.069		Broken	Grand Trunk
130	56.6	12125	90	A. R. A. "B"	Maryland	1909-11	.50	.10	1.00	.15	.075		Head Failures	Baltimore & Ohio
131	56.3	21508	85	P. R. R.	Carnegie	1895-99	.30 .50						Head Failures	Penna. Lines—S. W. System
132	56.0	1437	100	A. R. A. "A"	Maryland	1909	.58 .68	.07					Head Failures	Central of New Jersey
133	55.0	1100	80	A. S. C. E.	Penna.	1898							Broken	Long Island
134	54.4	22793	85	A. S. C. E.	Cambria	1903-07	.53 .63	.10	.80 1.10	.10 .20	.075		Head Failures, Broken	Atchison, Topeka & Santa Fe
135	54.1	16818	85	A. S. C. E.	Carnegie	1906-09	.45 .58	.10	.80 1.10	.10 .20	.04 .06		Head Failures	St. Louis & San Francisco
136	53.0	7282	85	P. S.	Illinois	1909-11	.45 .55	.10	.80 1.20	.05 .20			Broken Base	Vandalia
137	52.0	155686	80	A. S. C. E.	Illinois	1895-11	.48	.10	.96	.20			Broken, Broken Base	Lake Shore & Michigan Southern
138	51.6	1162	76	A. S. C. E.	B. I.	1903							Broken	St. Louis & San Francisco
139	51.0	8578	85	A. S. C. E.	Cambria	1901-07	.45 .55	.10	.80 1.20	.05 .20			Broken, Head Failures	Vandalia
140	50.7	101681	85	Mo. Pac.	Carnegie	1903-10	.43 .58	.10	.80 1.10	.20			Head Failures	Missouri Pacific

TABLE No. 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. Failures per 10,000 Tons	Tons Laid	Wt.	Section	Manufacturer	Year	Specified Chemical Composition C.	P.	Mn.	Si.	S.	Predominant Failures	Railroad
							OPEN-HEARTH RAIL						
1	378.5	8495	90	A. R. A. "B"	Bethlehem	1908-11	.72	.04	.875	.131	.06	Broken	Baltimore & Ohio
2	256.0	273	90	A. R. A. "A"	Bethlehem	1911-12	.725	.04	.875	.125		Broken	Baltimore & Ohio
3	181.6	53453	90	G. N.	Illinois	1909-11	.68	.04	.85	.20		Broken, Broken Base	Great Northern
4	158.1	4300	90	C. S.	Tenn. C. & I.	1908-09	.60	.085	.90	.20	.075	Head Failures	Galveston, Harrisburg & San Antonio
							.55	.05	.80	.15	.05		
5	156.0	34090	80	A. S. C. E.	Dominion I. & S.	1905-11	.65	.065	1.10	.20		Broken 30%, Head Failures 53%	Grand Trunk
6	147.0	4975	90	A. R. A. "A"	Illinois	1909-12	.725	.04	.875	.125		Broken	Baltimore & Ohio
							.65		.80				
7	123.8	22524	90	A. S. C. E.	Bethlehem	1907-10	.80	.04	1.05			Broken	Lehigh Valley
							.55		.80				
8	123.5	3075	85	Mo. P.	Tenn. C. & I.	1904-06	.65	.06	1.10	.20	.05	Broken 50%, Head Failures 50%	Missouri Pacific
							.67		.60	.05			
9	101.6	21941	100	A. R. A. "A"	Bethlehem	1910-12	.85	.04	.90	.20		Head Failures	Central of New Jersey
10	99.8	22048	90	G. N.	Bethlehem	1908-09	.62	.05	.80	.20		Broken 35%, Head Failures 60%	Great Northern
11	85.8	5487	90	A. R. A. "B"	Carnegie	1911-12	.725	.04	.875	.125		Broken	Baltimore & Ohio
12	74.9	7080	85	A. S. C. E.	Bethlehem	1911	.73	.04	.75	.20		Broken	Maine Central
13	73.2	3967	100	A. R. A. "B"	Maryland	1910-11	.75	.04	.875	.125		Head Failures	Baltimore & Ohio
							.65		.75	.05			
14	68.3	5975	90	A. R. A. "B"	Cambria	1910-11	.80	.04	1.00	.20		Broken	Baltimore & Ohio
							.66	.23	.71	.09	.032		
15	64.0	10845	100	P. S.	Bethlehem	1909-12	.75	.28	.78	.15	.045	Broken 53%, Head Failures 40%	Penna. Lines, East
							.68		.71				
16	63.9	43799	90	D. L. & W.	Bethlehem	1908-12	.80	.04	1.03		.055	Broken	Delaware, Lackawanna & Western
17	59.6	4041	100	A. R. A. "B"	Bethlehem	1910-12	.75	.04	.87	.125		Broken 46%, Head Failures 54%	Baltimore & Ohio
18	59.0	1218	80	A. S. C. E.	Bethlehem	1911	.71	.026	.80	.132	.036	Split Web	Central New England
							.63		.70				
19	56.7	35620	90	C. S.	Tenn. C. & I.	1908-12	.76	.04	1.00	.20		Broken	Illinois Central
20	55.9	7686	90	A. R. A. "B"	Maryland	1910-11	.725	.04	.875	.125		Head Failures	Baltimore & Ohio
							.59		.60				
21	55.0	5822	90	A. S. C. E.	Bethlehem	1908-11	.75	.04	.90	.20		Head Failures	Erie
							.63		.70	.07			
22	53.7	6144	75	B. & M.	Penna.	1910-11	.76	.04	1.00	.20	.06	Broken	Boston & Maine
							.55		.70				
23	53.0	10000	85	C. B. & Q.	Bethlehem	1908	.67	.04	1.00			Broken Base 47%, Split Head 41%	Chicago, Burlington & Quincy
									.70				
24	51.8	14459	85	A. R. A. "A"	Bethlehem	1908	.57	.04	1.00	.20	.06	Head Failures	Atchison, Topeka & Santa Fe
							.62			.05			
25	50.0	6100	85	P. S.	Illinois	1909-11	.75	.04	.80	.20		Broken 33%, Head Failures 53%	Vandalia

FERRO-TITANIUM BESSEMER

2500.0	100	85	P. S.	Illinois	1911	.45 .55	.10	.80 1.20	.05 .20		.30	Broken 33%, Broken Base 67%	Vandalia
106.0	1065	90	A. S. C. E.	Lackawanna	1909	.43 .53	.10	.80 1.10	.20		.05	Broken Base	Lehigh Valley
104.0	96	100	A. S. C. E.	Lackawanna	1909							All (1) Broken Base	Lake Shore & Mich. So.
93.5	40295	80	Dudley	Lackawanna	1909-11	.43 .65	.10	.90 1.10	.10 .20		.33	Broken, Broken Base	N. Y. C. & H. R. R. R
92.0	9082	90	A. S. C. E.	Lackawanna	1910	.47 .57	.10	.80 1.10	.20		.05	Broken Base	Lehigh Valley
80.5	3351	90	A. R. A. "B"	Maryland	1910-11	.50	.10	1.00	.125		.15 .30	Broken	Baltimore & Ohio
61.3	18442	80	Dudley	Lackawanna	1910-11	.43 .65	.10	.40 1.10	.10 .15		.33	Broken, Broken Base	N. Y. C. & H. R. R. R.
59.7	335	80	A. S. C. E.	Lackawanna	1909							Broken, Head Failure	Toledo, St. Louis & Western
58.0	13275	90	A. R. A. "A"	Lackawanna	1909-11	.43 .53	.10	.80 1.10	.20		.30	Broken	Chicago, Burlington & Quincy
56.0	35909	100	Dudley	Lackawanna	1909-11	.43 .70	.10	.10 .20	.075		F.T. .33	Broken, Broken Base	N. Y. C. & H. R. R. R.
50.0	3000	90	A. S. C. E.	Lackawanna	1910	.45 .55	.10	.90 1.15	.20			Broken, Broken Base	Philadelphia & Reading

FERRO-TITANIUM OPEN-HEARTH

1484.0	2750	80	A. S. C. E.	Lackawanna	1911	.52 .65	.04	.60 .90	.20			All (408) Broken Base	Great Northern
194.0	723	90	A. R. A. "B"	Maryland	1911	.725	.04	.875			F. T. 1.00	Head Failure	Baltimore & Ohio
121.2	1980	90	G. N.	Lackawanna	1909-10	.62 .75	.04	.70 1.00	.20			Head Failure	Great Northern
11.5	6900	90	A. S. C. E.	Bethlehem	1910	.70 .80	.04	.80			.05	Broken, Broken Base	Lehigh Valley.
91.2	1097	100	D. L. & W.	Bethlehem	1911	.80	.04	.75 1.05	.20			All (10) Broken	Delaware, Lackawanna & Western
60.0	1504	90	A. S. C. E.	Carnegie	1911	.70 .85	.04	.70 1.00	.20		.01	Broken, Split Web	Lehigh Valley

ELECTRIC STEEL

1092	916	90	A. R. A. "A"	Illinois	1910	.50 .66	.016 .064	.52 .76	.05 .20			Split Head	Union Pacific
510	389	80	A. S. C. E.	Illinois	1910							Head Failure	Lake Shore & Michigan Southern

TABLE No. 3—TABULATION OF KINDS OF FAILURES FOR DIFFERENT WEIGHTS OF RAIL CLASSIFIED AS BETWEEN BESSEMER AND OPEN-HEARTH STEEL

The figures for 1909, 1910 and 1911 are added for comparison. Fractions of decimals omitted. Odd weights of rail omitted.

PERCENTAGE OF FAILURES OF TOTAL FAILURES

Weight of Rail	Bessemer				Open-Hearth				Year
	Broken	Head Failures	Web Failures	Broken Base	Broken	Head Failures	Web Failures	Broken Base	
135-lb.	....	....	....	....	....	100	....	....	1911
135-lb.	....	....	....	....	3	94	3	....	1912
100-lb.	20	58	14	8	19	41	28	12	1909
100-lb.	34	47	9	10	23	56	13	8	1910
100-lb.	32	51	11	6	31	45	20	4	1911
100-lb.	41	36	8	15	28	51	7	14	1912
95-lb.	14	81	3	2	....	....	....	....	1910
95-lb.	25	68	6	1	....	....	....	....	1911
95-lb.	25	72	....	3	....	....	....	....	1912
90-lb.	17	74	6	3	34	51	12	3	1909
90-lb.	24	58	9	9	38	46	11	5	1910
90-lb.	21	62	6	11	42	41	9	8	1911
90-lb.	51	31	2	16	52	34	4	10	1912
85-lb.	16	70	6	8	21	64	9	6	1909
85-lb.	30	53	5	12	21	63	11	5	1910
85-lb.	28	53	6	12	24	58	11	12	1911
85-lb.	50	32	5	13	39	44	9	8	1912
80-lb.	16	73	6	5	15	60	19	6	1909
80-lb.	23	67	6	4	34	44	12	10	1910
80-lb.	21	67	6	6	28	38	8	26	1911
80-lb.	43	40	4	13	34	47	11	8	1912
75-lb.	28	52	18	2	....	....	....	....	1909
75-lb.	32	49	12	7	36	30	14	21	1910
75-lb.	25	52	17	6	59	5	7	29	1911
75-lb.	51	38	4	7	57	24	13	6	1912

In general, head failures predominate, except in the case of the 75-lb. Open-Hearth rail in 1911, to which attention was called in last year's report. There is a slight excess of broken rails in all weights except the 95-lb. of the Bessemer, and in the 75-lb. and 90-lb. Open-Hearth. This slight excess cannot be attributed to any one item.

TABLE NO. 4—ORDER OF SUPERIORITY OF DIFFERENT SECTIONS WITH COMPARISONS FOR LAST TWO YEARS.

An examination of this table makes it evident that the section as a rule has little influence on the quality of the material. Under 100 lbs. Bessemer, N. Y. N. H. & H. ranks 1 in 1912, 7 in 1911 and 1 in 1910. Dudley ranks 2 in 1912, 4 in 1911 and 8 in 1910. A study of the detail reports makes it clear that other factors than the section are responsible for the difference in performance of different lots of rail. Small differences in chemical composition are of not much importance. Density of traffic, speed and wheel loads are of importance principally as they determine the weight of rail. Probably the majority of rail failures are due to faulty material; i. e., segregation, slag inclusions, pipes, etc.

TABLE No. 4—ORDER OF SUPERIORITY OF VARIOUS RAIL SECTIONS, BASED ON RELATIVE NUMBER OF RAIL FAILURES PER 10,000 TONS.

CLASSIFIED ACCORDING TO WEIGHT AND MATERIAL

OCTOBER 31, 1912

Order	100-lb.				90-lb.				85-lb.				80-lb.				75-lb.			
	Section	Tons Laid	Order in '11	Order in '10	Section	Tons Laid	Order in '11	Order in '10	Section	Tons Laid	Order in '11	Order in '10	Section	Tons Laid	Order in '11	Order in '10	Section	Tons Laid	Order in '11	Order in '10
	BESSEMER RAIL																			
1	N.Y.N.H.&H.	29,791	7	1	A. R. A. "B"	172,569	4	5	A. R. A. "A"	15,694	3	6	A. R. A. "A"	52,874	1	1	Mo. Pac.	89,498	1	1
2	Dudley	179,284	4	8	A. R. A. "A"	100,102	1	1	D. & R. G.	119,411	....	....	A. R. A. "B"	3,515	....	....	O. W. R. & N.	21,003	3	....
3	P. & R.	9,900	6	6	A. S. C. E.	848,368	2	3	O.W.R.& N.	4,324	1	....	Dudley	255,178	2	2	Dudley	104,107	....	....
4	P. R. R.	480,605	1	4	C. S.	112,730	3	4	P. R. R.	631,988	2	2	A. S. C. E.	1,853,777	3	3	A. S. C. E.	571,767	2	3
5	P. S.	99,523	3	3	G. N.	45,732	5	2	Mo. Pac.	168,723	4	1	Cam. 540.	6,141	4	4	C. S.	94,897	4	4
6	A. R. A. "B"	131,647	2	2					P. S.	147,008	5	3					B. & M.	120,778	5	2
7	A. R. A. "A"	33,013	8	5					A. S. C. E.	2,700,944	6	4					I. C.-1889	2,890	....	....
8	A. S. C. E.	542,614	5	7					C. B. & Q.	127,150	7	5								
	OPEN-HEARTH RAIL																			
1	Dudley	50,105	2	5	Santa Fe	132,538	1	1	P. R. R.	52	....	....	A. R. A. "A"	14,587	....	....	C. S.	54,205	1	1
2	D. L. & W.	33,089	1	....	A. R. A. "A"	450,207	2	2	Dudley	5,291	....	....	Dudley	17,834	....	....	Dudley	42,422	....	....
3	P. & R.	25,968	6	3	C. S.	163,758	3	4	D. & R. G.	17,912	....	....	N.Y.N.H.&H.	22,008	1	....	A. S. C. E.	81,057	3	2
4	A. R. A. "B"	132,948	4	1	A. S. C. E.	129,189	6	6	A. S. C. E.	574,946	2	1	A. S. C. E.	448,446	2	....	B. & M.	6,144	2	....
5	P. S.	202,351	5	6	A. R. A. "B"	216,126	5	3	P. S.	76,485	3	2								
6	A. S. C. E.	243,352	3	4	D. L. & W.	70,592	4	5	C. B. & Q.	31,080	5	5								
7	N.Y.N.H.&H.	42,892	8	7					A. R. A. "A"	30,191	4	3								
8	A. R. A. "A"	65,021	7	2					Mo. Pac.	3,075	1	4								
9	P. R. R.	2,333	9	8																

(NOTE.—Rail not reported in 1912 is not considered in figuring order for years 1911 and 1910.)

TABLE No. 5—STATEMENT OF HEAD FAILURES IN DIMINISHING ORDER, WITH COMPARISON FOR PAST TWO YEARS

This table was prepared with a view to discovering whether or not the number of head failures was influenced by the section. That is, whether a thin head or deep head is the better and whether a high stiff or low flexible section is the better.

The design has apparently little influence on the number of failures.

It is interesting to note, however, that the following sections stand, in all three years, among the ten sections having the greatest number of failures, possibly indicating, in these cases, a fault in design.

BESSEMER

Section	Weight	Order in 1912	Order in 1911	Order in 1910	Deep or Thin Head	High or Low Design
C. S.	90	1	4	3	T	H
A. R. A. "B"	90	3	1	1	D	L
Cambria 540	80	4	9	7	D	L
C. B. & Q	85	8	8	4	T	L

OPEN-HEARTH

Section	Weight	Order in 1912	Order in 1911	Order in 1910	Deep or Thin Head	High or Low Design
C. R. R. of N. J.	135	1	1	....	D	H
G. N.	90	5	4	9	T	H
A. R. A. "A"	85	7	9	10	T	H
A. S. C. E.	80	8	5	5	D	L

TABLE No. 5—STATEMENT OF HEAD FAILURES PER 10,000 TONS OF RAIL LAID ARRANGED IN DIMINISHING ORDER

BESSEMER RAIL

Order	Section	Weight	Tons Laid	Number of "Head Failures" per 10,000 Tons of Rail Laid 1912	1911	1910	Deep or Thin Head	High or Low Design	Order in Year 1911	Order in Year 1910
1	C. S.	90	112,730	57.0	47.1	42.8	T	H	4	3
2	G. N.	90	45,738	48.0	34.8	11.6	T	L	6	16
3	A. R. A. "B"	90	172,509	46.3	73.0	84.3	D	L	1	1
4	Cambria 540	80	6,141	39.1	27.6	27.0	D	L	9	7
5	A. R. A. "A"	100	33,013	37.0	66.5	15.9	T	H	2	13
6	P. S.	85	147,003	33.2	21.0	29.6	D	L	14	6
7	A. S. C. E.	100	542,614	33.1	21.5	20.2	D	L	12	9
8	C. B. & Q.	85	127,150	29.3	30.4	39.3	T	L	8	4
9	G. N.	75	94,897	26.3	......	......	T	L	......	......
10	Mo. Pac	85	168,723	25.7	20.1	1.2	D	L	13	24
11	B. & M	75	120,778	25.3	23.5	0.3	T	L	11	25
12	A. S. C. E	90	848,368	22.8	25.6	31.4	D	L	10	5
13	A. S. C. F	75	6,253	20.8	......	......	D	L	......	......
14	P. S.	100	99,523	18.2	16.9	13.0	D	L	16	15
15	A. R. A. "B"	100	131,647	17.6	12.9	9.7	D	L	20	17
16	A. S. C. E	85	2,700,944	17.5	17.1	18.1	D	L	15	12
17	P. & R.	100	9,900	17.2	53.9	20.3	D	L	3	8
18	A. S. C. E.	80	1,853,777	14.2	14.2	18.5	D	L	18	11
19	O. W. R. & N.	85	4,334	13.9	......	......	D	L	......	......
20	A. S. C. E	79	8,000	13.7	......	......	D	L	......	......
21	A. R. A. "A"	90	100,102	12.3	11.0	13.4	T	H	21	14
22	P. R. R.	85	631,968	11.9	9.2	8.6	D	L	22	18
23	Dudley	80	255,178	9.8	7.0	7.9	T	H	25	20
24	D. & R. G.	85	119,411	9.2	......	......	D	L	......	......
25	A. S. C. E.	75	571,767	8.8	6.2	8.5	D	L	26	19
26	B. & A.	95	61,678	8.4	......	......	T	L	......	......
27	Dudley	100	179,284	4.3	9.0	19.9	T	H	23	10
28	Dudley	75	104,107	4.1	......	......	T	H	......	......
29	P. R. R.	100	480,606	4.0	2.9	4.0	D	L	29	21
30	A. R. A. "B"	80	3,515	2.8	......	......	D	L	......	......
31	Mo. Pac	75	89,498	2.1	1.7	1.7	D	L	31	23
32	A. R. A. "A"	85	15,694	1.3	7.5	66.2	T	H	24	2
33	N. Y. N. H. & H.	100	29,791	1.0	44.9	2.7	D	H	5	22
34	O. W. R. & N.	75	21,003	0.5	3.4	......	D	L	28	......
35	A. R. A. "A"	80	52,875	0.0	......	......	T	H	......	......

TABLE No. 5—STATEMENT OF HEAD FAILURES PER 10,000 TONS OF RAIL LAID ARRANGED IN DIMINISHING ORDER—CONTINUED

OPEN-HEARTH RAIL

Order	Section	Weight	Tons Laid	Number of "Head Failures" per 10,000 Tons of Rail Laid			Deep or Thin Head	High or Low Design	Order in Year 1911	Order in Year 1910
				1912	1911	1910				
1	C. R. R. of N. J.	135	2,098	152.4	366.7	......	D	H	1	......
2	Mo. Pac	85	3,075	65.0	2.2	20.2	D	H	22	3
3	D. L. & W.	90	70,592	31.4	3.6	5.6	D	L	18	13
4	A. R. A. "A"	100	65,021	24.6	10.9	0.5	T	H	10	20
5	G. N.	90	131,721	20.0	20.1	7.3	T	H	4	9
6	C. S.	90	163,758	18.9	5.9	5.5	T	H	15	14
7	A. R. A. "A"	85	39,191	18.4	12.6	7.1	T	H	9	10
8	A. S. C. E.	80	448,446	14.0	17.0	12.2	D	L	5	5
9	A. R. A. "B"	90	216,126	13.6	10.1	10.9	D	L	11	6
10	A. S. C. E.	100	243,352	11.0	3.3	6.2	D	L	20	11
11	A. S. C. E.	90	129,189	10.7	15.1	20.1	D	L	7	4
12	P. S.	100	202,351	9.7	6.9	8.2	D	L	13	7
13	C. B. & Q.	85	31,000	9.3	17.0	23.0	T	L	6	2
14	P. S.	85	76,485	8.9	3.3	......	D	L	12	......
15	N. Y. N. H. & H.	100	42,892	7.4	3.6	2.0	D	H	17	18
16	A. R. A. "A"	90	450,207	6.7	5.7	8.1	T	H	16	8
17	A. S. C. E.	85	574,946	5.5	3.3	5.8	D	L	19	12
18	A. R. A. "B"	100	132,948	5.2	6.4	10.9	D	L	14	6
19	Santa Fe	90	132,538	5.1	2.4	1.9	T	H	21	19
20	P. & R.	100	25,968	5.0	14.2	8.7	D	L	8	15
21	P. R. R.	100	2,333	4.3	......	......	D	L	......	......
22	A. S. C. E.	75	81,057	2.8	0.2	3.3	D	L	24	16
23	C. S.	75	54,205	2.0	1.0	2.1	T	H	23	17
24	Dudley	85	5,291	2.0	......	......	T	H	......	......
25	Dudley	100	50,105	1.6	......	......	T	H	......	......
26	D. L. & W.	100	33,089	1.5	......	......	D	L	......	......
27	Dudley	75	42,422	1.4	......	......	T	H	......	......
28	N. Y. N. H. & H.	80	22,008	0.9	......	......	D	H	......	......
29	D. & R. G.	85	17,912	0.6	......	......	D	L	......	......
30	Dudley	80	17,834	0.0	......	......	T	H	......	......
31	A. R. A. "A"	80	14,587	0.0	......	......	T	H	......	......
32	B. & M.	75	6,144	0.0	......	......	T	L	......	......

TABLE No. 5—STATEMENT OF HEAD FAILURES PER 10,000 TONS OF RAIL LAID ARRANGED IN DIMINISHING ORDER—CONTINUED

SPECIAL ALLOYS

Order	Section	Weight	Tons Laid	Number of "Head Failures" per 10,000 Tons of Rail Laid 1912	1911	1910	Deep or Thin Head	High or Low Design	Order in Year 1911	Order in Year 1910
	FERRO-TITANIUM BESSEMER									
1	G. N.	90	1,980	85.9	19.5	......	T	L	3	......
2	A. R. A. "B"	90	7,703	20.8	12.5	......	D	L	4	......
3	A. R. A. "A"	90	13,513	8.9	0.7	......	T	H	7	......
4	A. S. C. E.	90	22,043	6.3	56.9	2.8	D	L	2	2
5	Dudley	80	58,737	3.4	1.2	......	T	H	6	......
6	Dudley	100	50,012	3.2	2.3	......	T	H	5	......
7	A. R. A. "B"	100	10,816	2.8	......	......	D	L	......	......
8	A. S. C. E.	80	3,606	2.8	......	......	D	L	......	......
9	A. R. A. "A"	100	10,909	1.9	......	......	T	H	......	......
10	A. S. C. E.	85	19,699	0.0	......	......	D	L	......	......
11	A. S. C. E.	100	4,754	0.0	73.5	......	D	L	1	......
	FERRO-TITANIUM OPEN-HEARTH									
1	A. R. A. "B"	90	723	138.3	......	......	D	L	......	......
2	A. S. C. E.	90	11,295	16.8	......	......	D	L	......	......
3	L. V.	110	12,967	8.5	26.6	......	D	H	1	......
4	A. R. A. "A"	100	16,234	5.5	2.3	......	T	H	3	......
5	D. L. & W.	100	1,308	0.0	......	......	D	L	......	......
	MAYARI—CHROME NICKEL—BESSEMER									
1	A. R. A. "B"	100	1,967	10.0	......	......	D	L	......	......
2	P. S.	100	17,741	2.2	......	......	D	L	......	......
3	A. S. C. E.	85	30,700	0.0	6.0	15.7	D	L	1	1
4	P. S.	85	7,309	0.0	......	......	D	L	......	......
5	N. Y. N. H. & H.	100	5,574	0.0	10.0	......	D	H	2	......
6	P. S.	100	3,830	0.0	......	......	D	L	......	......
7	A. S. C. E.	85	3,370	0.0	......	......	D	L	......	......
	MAYARI—CHROME NICKEL—OPEN-HEARTH									
1	P. S.	100	1,707	41.0	......	......	D	L	......	......
2	A. R. A. "B"	90	566	0.0	812.7	565.2	D	L	1	1
3	N. Y. N. H. & H.	100	333	0.0	......	......	D	H	......	......
4	D. L. & W.	100	240	0.0	......	......	D	L	......	......

TABLE NO. 6.

This table has been compiled to show the great variation in the rate of rail failures for the same weights and sections under conditions as nearly uniform as could be determined from the reports.

A. R. A. "A" 100-lb. rail, for instance, varied in 1912 from 24.3 failures per 10,000 tons on the Pennsylvania Lines, N. W. System, to 364.8 on the S. W. System.

A. R. A. "B" 100-lb. failures on the Baltimore & Ohio Railroad were 81.5 for Maryland rail and 124.0 for Cambria rail.

P. S. 100-lb. rail, Pennsylvania Lines, N. W. System, 32.9 failures per 10,000 tons for Carnegie rail and 2.5 for Illinois.

A. S. C. E. 90-lb. on Erie Railroad, 35.0 for Lackawanna and 617.0 for Illinois, with 186.0 for Carnegie.

In the Open-Hearth rail, on the Central Railroad of New Jersey. 100-lb. A. R. A. "A" varied from 5.8 to 101.6.

A. R. A. "B" 90-lb. on the Baltimore & Ohio Railroad varied from 24.6 to 378.5.

Similar variations may be found throughout the report and point to the same conclusion as was reached last year, i. e., "Variations (in performance of rails) must be attributed to variations in the performance of different mills, and also to variations in the performance of the same mill at different times."

TABLE No. 6—COMPARISONS FROM REPORT OF RAIL FAILURES FOR YEAR ENDING OCTOBER 31, 1912, SHOWING DIFFERENT PERFORMANCES OF RAIL UNDER SIMILAR CONDITIONS—BESSEMER STEEL

Year Laid	Tons Laid	Manufacturer	Weight	Section	Carbon	Railroad	Failures per 10,000 Tons 1912	1911	1910	Remarks
1909	2,121	Carnegie	100-lb.	A. R. A. "A"	.51	Balto. & Ohio	89.5	147.6	51.9	Note great difference in failures of same lot of rail on Penna. Lines, N. W. and S. W. Systems. High carbon rail on C. R. R. of N. J. shows better than low carbon on B. & O.-different mills.
1909	1,643	Carnegie	100-lb.	A. R. A. "A"	.50	P. L. N. W. S.	24.3	18.2	30.4	
1909	1,535	Carnegie	100-lb.	A. R. A. "A"	.50	P. L. S. W. S.	364.8	254.1	117.3	
1909	1,437	Maryland	100-lb.	A. R. A. "A"	.58-.68	C. R. R. of N. J.	56.0	21.0	13.0	
1909-10	2,173	Cambria	100-lb.	A. R. A. "B"	.51	B. & O.	124.0	73.7	4.8	Same road, same kind of rail. Better results from Maryland rail.
1909-11	19,196	Maryland	100-lb.	A. R. A. "B"	.51	B. & O.	81.5	53.6	27.0	
1905-10	122,080	Illinois	100-lb.	A. S. C. E.	.52	L. S. M. S.	114.0	36.0	39.0	Same road, different mills. Better results from lower carbon.
1905-10	41,439	Lackawanna	100-lb.	A. S. C. E.	.54	L. S. M. S.	271.0	96.0	92.0	
1909-11	26,466	Carnegie	100-lb.	P. S.	.50	P. L. N. W. S.	32.9	16.4	11.1	Results close in Carnegie rail. Wide variation in Illinois rail.
1909-12	16,857	Carnegie	100-lb.	P. S.	.50	P. L. S. W. S.	31.4	14.6	24.5	
1909-11	3,926	Illinois	100-lb.	P. S.	.50	P. L. N. W. S.	2.5	2.7	3.0	
1911-12	1,921	Illinois	100-lb.	P. S.	.50	P. L. S. W. S.	72.9	5.7	....	
1909-11	6,829	Carnegie	90-lb.	A. R. A. "A"	.50	B. & O.	294.0	98.5	177.0	Wide variation in 1910 and 1911. Results closer in 1912.
1908-11	15,457	Illinois	90-lb.	A. R. A. "A"	.50	B. & O.	262.0	24.0	19.0	
1909-11	7,172	Cambria	90-lb.	A. R. A. "B"	.50	B. & O.	149.0	114.0	74.0	Wide variation in results from different mills. Same road.
1908-11	36,935	Carnegie	90-lb.	A. R. A. "B"	.50	B. & O.	191.0	246.0	304.0	
1909-11	12,135	Maryland	90-lb.	A. R. A. "B"	.50	B. & O.	56.6	45.0	41.0	
1909-12	15,789	Carnegie	90-lb.	A. R. A. "B"	.45-.55	N. Pacific	62.7	43.7	33.0	Wide variation in results from different mills.
1909-11	18,172	Illinois	90-lb.	A. R. A. "B"	.45-.55	N. Pacific	12.1	9.9	3.1	
1909-11	37,143	Lackawanna	90-lb.	A. R. A. "B"	.45-.55	N. Pacific	14.0	4.3	4.0	
1907	2,204	Cambria	90-lb.	A. S. C. E.	.54-.64	Central N. J.	63.0	141.0	154.0	Phosphorus not to exceed 0.10 in all. Low carbon shows best results.
1907-09	7,265	Lackawanna	90-lb.	A. S. C. E.	.45-.64	Central N. J.	16.5	23.3	56.0	
1908	4,216	Maryland	90-lb.	A. S. C. E.	.45-.55	Central N. J.	12.0	26.7	77.0	
1905-10	27,400	Carnegie	90-lb.	A. S. C. E.	.50-.60	C. C. C. & St. L.	140.0	100.0	237.0	Same chemistry, same road, wide difference in results.
1906-10	84,435	Illinois	90-lb.	A. S. C. E.	.50-.60	C. C. C. & St. L.	189.0	76.6	81.0	
1906	5,250	Lackawanna	90-lb.	A. S. C. E.	.50-.60	C. C. C. & St. L.	577.0	221.0	190.0	
1905-08	8,313	Lackawanna	90-lb.	A. S. C. E.	.45-.58	D. & H.	2.2	0.0	....	Low carbon gave best results. Same road, different mills.
1906-10	23,493	Maryland	90-lb.	A. S. C. E.	.53-.57	D. & H.	67.6	58.9	97.0	
1906-11	78,445	Carnegie	90-lb.	A. S. C. E.	.45-.58	Erie	186.0	93.0	99.0	Same chemistry, same road, different mills. Widely different results.
1906-11	18,184	Illinois	90-lb.	A. S. C. E.	.45-.58	Erie	617.0	49.0	130.0	
1906-11	55,275	Lackawanna	90-lb.	A. S. C. E.	.45-.58	Erie	35.0	17.0	13.8	
1903-09	6,396	Cambria	90-lb.	A. S. C. E.	.45-.55	Lehigh Valley	87.5	118.0	76.0	Wide contrast between rail rolled by Maryland Steel Co., and that from other mills.
1903-09	78,112	Carnegie	90-lb.	A. S. C. E.	.45-.55	Lehigh Valley	92.2	79.6	116.0	
1902-09	8,830	Maryland	90-lb.	A. S. C. E.	.45-.55	Lehigh Valley	10.2	23.8	122.3	
1901-10	67,963	Lackawanna	90-lb.	A. S. C. E.	.45-.55	Lehigh Valley	61.5	40.3	86.5	

1902–11	131,653	Maryland	90-lb.	A. S. C. E.	.42–.64	Phil. & Read	3.4	11.4	22.1	Wide contrast between Maryland rail and that from other mills in 1912 failure. Other years not so marked.
1905–11	8,819	Lackawanna	90-lb.	A. S. C. E.	.45–.64	Phil. & Read	39.6	13.4	19.4	
1905–10	5,450	Cambria	90-lb.	A. S. C. E.	.50–.64	Phil. & Read	20.2	29.3	56.8	
1905–10	8,152	Carnegie	90-lb.	A. S. C. E.	.50–.64	Phil. & Read	12.2	19.6	25.8	
1906–11	35,956	Carnegie	90-lb.	C. S.	.50–.60	Union Pacific	164.4	98.3	113.8	Different results from different mills.
1906–07	5,637	Lorain	90-lb.	C. S.	.50–.60	Union Pacific	61.3	32.1	44.5	
1909–12	36,650	Illinois	90-lb.	C. S.	.50–.60	Union Pacific	107.0	48.1	51.5	
1908	10,927	Illinois	90-lb.	G. N.	.43–.53	Grt. Nor.	89.6	75.6	27.0	Same section, same road, same chemistry, different results.
1908–09	14,578	Lackawanna	90-lb.	G. N.	.48	Grt. Nor.	468.5	119.7	3.0	
1905–09	187,100	Col. F. & I.	85-lb.	A. S. C. E.	.46–.58	A. T. & St. Fe.	17.6	21.7	20.7	Same road and section, different chemistry, different results.
1904–09	40,205	Maryland	85-lb.	A. S. C. E.	.52–.65	A. T. & St. Fe.	62.4	30.1	20.8	
1903–07	3,230	Illinois	85-lb.	A. S. C. E.	.47	B. & O.	1050.0	93.0	31.0	Same section, same road, chemistry slightly different, different results, different mills.
1903–08	143,035	Carnegie	85-lb.	A. S. C. E.	.493	B. & O.	92.6	53.5	54.0	
1903–07	51,295	Cambria	85-lb.	A. S. C. E.	.498	B. & O.	27.8	20.8	23.0	
1903–08	43,212	Maryland	85-lb.	A. S. C. E.	.52	B. & O.	43.8	27.7	25.0	
1903–08	12,785	Cambria	85-lb.	A. S. C. E.	.40–.55	G. R. & I.	115.0	44.6	67.7	Same mill, same section, same chemistry, same road, different location.
1903–07	5,221	Cambria	85-lb.	A. S. C. E.	.50	G. R. & I.	34.4	1.9	1.9	
1901–08	94,500	Maryland	85-lb.	A. S. C. E.	.50–.58	Norfolk & Western	1.8	3.0	4.0	Same road, same section, same chemistry, different results from different mills.
1901–08	28,000	Cambria	85-lb.	A. S. C. E.	.50–.58	Norfolk & Western	2.5	1.8	10.0	
1901–08	86,500	Carnegie	85-lb.	A. S. C. E.	.50–.58	Norfolk & Western	7.1	2.9	15.0	
1905–12	24,392	Cambria	85-lb.	A. S. C. E.	.43–.58	Southern	33.2	4.8	17.1	Same road, same section, same chemistry, different mills, different results, different years.
1903–08	13,733	Carnegie	85-lb.	A. S. C. E.	.43–.58	Southern	8.8	6.5	43.6	
1907–09	58,000	Col. F. & I.	85-lb.	C. B. & Q.	.48–.58	C. B. & Q.	29.4	14.2	18.3	Same road, same section, same chemistry, different mills, different results.
1907–08	65,000	Illinois	85-lb.	C. B. & Q.	.48–.58	C. B. & Q.	103.5	53.6	78.1	
1909–12	3,897	Cambria	85-lb.	P. S.	.40–.55	G. R. & I.	38.5	20.7	17.7	Same section, same mill, same chemistry, different locations, different results.
1909–12	4,877	Cambria	85-lb.	P. S.	.50	G. R. & I.	6.1	3.6	9.6	
1909–12	17,190	Carnegie	85-lb.	P. S.	.50	P. L. N. W. S.	147.2	156.6	168.0	Same section, road and chemistry, different mills and different results.
1908–12	1,600	Cambria	85-lb.	P. S.	.50	P. L. N. W. S.	25.0	120.0	100.0	
1902–05	7,720	Cambria	80-lb.	A. S. C. E.	.50	Hocking Valley	129.5	2.4	....	Same as above.
1902–06	12,367	Carnegie	80-lb.	A. S. C. E.	.50	Hocking Valley	35.5	2.4	....	
1896–10	158,515	Illinois	80-lb.	A. S. C. E.	.40–.50	M. St. P. & S. S. M.	26.5	....	....	Same section, road and chemistry, different mills and different results.
1904–07	9,076	Lackawanna	80-lb.	A. S. C. E.	.40–.50	M. St. P. & S. S. M.	118.9	....	....	
1904–05	7,474	Carnegie	80-lb.	A. S. C. E.	.50–.60	Union Pacific	208.7	192.0	97.3	Same section and road, different mills, n›e greater number of failures with higher carbon limit.
1901–08	64,437	Col. F. & I.	80-lb.	A. S. C. E.	.49–.57	Union Pacific	63.6	29.0	39.3	
1899–07	54,222	Illinois	80-lb.	A. S. C. E.	.46–.56	Union Pacific	66.4	19.3	35.5	
1904	3,511	Lackawanna	80-lb.	A. S. C. E.	.50–.60	Union Pacific	162.3	185.8	122.9	
1901–04	22,727	Illinois	75-lb.	A. S. C. E.	.40–.50	S. P. L. A. & S. L.	7.5	....	....	Same as above.
1901–05	9,184	Ougree	75-lb.	A. S. C. E.	.48–.58	S. P. L. A. & S. L.	94.7	....	....	

TABLE No. 6—COMPARISONS FROM REPORTS OF RAIL FAILURES FOR YEAR ENDING OCTOBER 31, 1912—CONTINUED

OPEN-HEARTH STEEL

Year Laid	Tons Laid	Manufacturer	Weight	Section	Carbon	Railroad	Failures per 10,000 Tons 1912	1911	1910	Remarks
1910-12	21,941	Bethlehem	100-lb.	A. R. A. "A"	.67-.85	C. R. R. of N. J.	101.6	55.6	2.0	Same section and road, different mills, chemistry practically the same.
1909-12	8,578	Penna.	100-lb.	A. R. A. "A"	.70-.85	C. R. R. of N. J.	5.8	5.4	6.0	
1910-11	3,967	Maryland	100-lb.	A. R. A. "B"	.75	B. & O.	73.2	30.2	....	Same section, chemistry and road, different mills and different results.
1910-12	4,041	Bethlehem	100-lb.	A. R. A. "B"	.75	B. & O.	59.6	51.0	....	
1910-12	22,341	Cambria	100-lb.	A. R. A. "B"	.75	B. & O.	9.4	6.0	....	
1908-12	17,706	Bethlehem	100-lb.	N.Y.N.H.&H.	.70-.80	N. Y. N. H. & H.	36.9	21.0	40.0	Phosphorus 0.04.
1908-12	16,684	Penna.	100-lb.	N.Y.N.H.&H.	.70-.85	N. Y. N. H. & H.	15.0	39.0	1.0	Phosphorus 0.035.
1909-12	10,845	Bethlehem	100-lb.	P. S.	.66-.75	Penna. East	64.0	42.0	35.0	Different results from different mills. Other items the same.
1907-12	43,781	Cambria	100-lb.	P. S.	.66-.75	Penna. East	17.0	16.0	10.0	
1908-12	13,722	Carnegie	100-lb.	P. S.	.69	Penna. East	10.0	5.0	14.0	
1911-12	11,500	Carnegie	90-lb.	A. R. A. "A"	.725	B. & O.	14.8	4.3	....	Different results from different mills. Other items the same.
1909-12	4,975	Illinois	90-lb.	A. R. A "A"	.725	B. & O.	147.0	17.2	10.5	
1908-11	8,495	Bethlehem	90-lb.	A. R. A. "B"	.72	B. & O.	378.5	284.7	279.4	All items same except mills. Note widely different results.
1909-11	13,010	Illinois	90-lb.	A. R. A. "B"	.72	B. & O.	24.6	6.9	7.3	
1911 12	9,995	Bethlehem	90-lb.	A. S. C. E.	.70-.85	P. & R.	33.0	14.1	....	Different mills, different results.
1911-12	15,063	Penna.	90-lb.	A. S. C. E.	.70-.85	P. & R.	4.6	2.1	....	
1911	5,040	Carnegie	90-lb.	A. S. C. E.	.70-.85	P. & R.	0.0	0.0	....	
1908-12	43,799	Bethlehem	90-lb.	D. L. & W.	.68-.80	D. L. & W.	63.9	34.5	21.7	Different mills, different results.
1908-12	26,793	Lackawanna	90-lb.	D. L. & W.	.68-.80	D. L. & W.	9.7	2.3	4.8	
1909-11	53,453	Illinois	90-lb.	G. N.	.68	Great Northern	181.6	63.4	....	Different mills, different results.
1910-12	19,270	Lackawanna	90-lb.	G. N.	.68	Great Northern	8.8	17.9	....	
1909-11	10,963	Bethlehem	85-lb.	A. S. C. E.	.62-.75	Norfolk & Western	20.0	23.7	19.0	Different mills, different results.
1909-12	10,690	Cambria	85-lb.	A. S. C. E.	.62-.75	Norfolk & Western	2.8	8.1	....	
1908	10,000	Bethlehem	85-lb.	C. B. & Q.	.55-.67	C. B. & Q.	53.0	19.0	30.0	Different mills, different results.
1909	21,000	Col. F. & I.	85-lb.	C. B. & Q.	.55-.65	C. B. & Q.	3.8	6.7	21.9	
1911	1,218	Bethlehem	80-lb.	A. S. C. E.	.71	Central New England	59.0	....	....	Different mills, different results, note also difference in carbon.
1911	2,364	Penna.	80-lb.	A. S. C. E.	.77	Central New England	17.8	12.0	....	

TABLES NOS. 7, 8 AND 9—CLASSIFICATION OF FAILURES ACCORDING TO POSITION IN INGOT.

Table No. 7 shows detail information furnished by individual roads.

Table No. 8 shows this information summarized according to weight and section of rail.

Table No. 9 shows this information summarized according to manufacturer.

All tables are divided, showing Bessemer and Open-Hearth rail separately.

The preponderance of "A" rail failures is not so great this year as last, being only 30.2 per cent. for the Bessemer, as against 43.7 per cent. last year. In the Open-Hearth, "A" rails made up 21.3 per cent. of the failures this year as against 22.9 per cent. last year.

This is still a higher percentage than from any other part of the ingot.

Last year it was noted that the Ferro-Titanium rail, both Bessemer and Open-Hearth showed a smaller percentage of "A" rail failures than the ordinary rail of similar process. This is not true this year, the percentages being as follows:

Ordinary Bessemer	30.2 per cent.
Ferro-Titanium Bessemer	31.0 per cent.
Ordinary Open-Hearth	21.3 per cent.
Ferro-Titanium Open-Hearth	21.6 per cent.

There is in general a more uniform distribution of the failures among the different positions in the ingot.

TABLE No. 7—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN INGOT

Weight	Section	Manufacturer	Position in Ingot A	B	C	D	E	F, etc.	Un-known	Total	Railroad
			BESSEMER RAIL								
100	A. R. A. "A"	Carnegie	1	7	9			1	1	19	Baltimore & Ohio
100	A. R. A. "A"	Maryland	4	1	1	1			1	8	Central of New Jersey
100	A. R. A. "A"	Carnegie		7	8				11	26	Pittsburgh & Lake Erie
100	A. R. A. "A"	Carnegie		49		1		1	5	56	Pennsylvania S. W. System
100	A. R. A. "B"	Carnegie	23	28	22	6	3		36	118	Bessemer & Lake Erie
100	A. R. A. "B"	Cambria	11	5	5	3	6		5	35	Baltimore & Ohio
100	A. R. A. "B"	Maryland	88	15	15	17	11	1	11	158	Baltimore & Ohio
100	A. R. A. "B"	Carnegie		4	2				3	9	Pittsburgh & Lake Erie
100	A. S. C. E.	Maryland	9	2	1	1			179	192	Baltimore & Ohio
100	A. S. C. E.	Illinois	27	3	2	1	5		29	67	Chicago, Burlington & Quincy
100	A. S. C. E.	Illinois	34	40	53	2			1273	1402	Lake Shore & Michigan Southern
100	A. S. C. E.	Illinois	12	17	28	2			48	107	Michigan Central
100	Dudley	Lackawanna	30	14	22				44	110	Boston & Albany
100	Dudley	Lackawanna	49	65	28	5	2		561	710	New York Central & Hudson River
100	P. & R.	Maryland	6	1	4	2				13	Philadelphia & Reading
100	P. & R.	Carnegie	6	2						8	Philadelphia & Reading
100	P. R. R.	Maryland		4	6	1	3		14	28	Cumberland Valley
100	P. R. R.	Maryland		9	3	1	4	1	286	304	Pennsylvania Lines East
100	P. S.	Carnegie	2	41	24	2	1	1	16	87	Pennsylvania Lines, N. W. System
100	P. S.	Carnegie		20	10			1	22	53	Pennsylvania Lines, S. W. System
100	P. S.	Illinois	7	1	6					14	Pennsylvania Lines, S. W. System
100	P. S.	Cambria	3	1		14	1		4	23	Pennsylvania Lines, S. W. System
100	P. S.	Cambria	23	26	11	15	12	1	12	100	Pennsylvania Lines, East
100	P. S.	Maryland	19	9	12	5			11	56	Pennsylvania Lines East
100	P. S.	Lackawanna	11	1	1				3	16	Pennsylvania Lines East
90	A. R. A. "A"	Carnegie	55	15	53	37	1	4	37	202	Baltimore & Ohio
90	A. R. A. "A"	Illinois	66	36	115	77	10	2	95	401	Baltimore & Ohio
90	A. R. A. "A"	Lackawanna	19	10	32	9	5		343	418	Lehigh Valley
90	A. R. A. "A"	Illinois		6	8	3				17	Oregon Short Line
90	A. R. A. "A"	Illinois	13	10	8	13			1	45	Southern Pacific
90	A. R. A. "A"	Illinois	19	5	4	9				37	Union Pacific
90	A. R. A. "B"	Illinois	10	3	4				1	18	Baltimore & Ohio
90	A. R. A. "B"	Carnegie	251	95	203	61	14	14	54	692	Baltimore & Ohio
90	A. R. A. "B"	Maryland	37	7	7	8	5	1	5	70	Baltimore & Ohio

90	A. R. A. "B"	Cambria	39	16	10	18	17	10	5	115	Baltimore & Ohio
90	A. R. A. "B"	Carnegie	2	4	7	6				19	Hocking Valley
90	A. R. A. "B"	Illinois	1		1		2	2		6	Hocking Valley
90	A. R. A. "B"	Illinois	4	5	2	2		1	8	22	Northern Pacific
90	A. R. A. "B"	Lackawanna	8	2	4	15		14	9	52	Northern Pacific
90	A. R. A. "B"	Carnegie	36	4	28	3	1	3	24	99	Northern Pacific
90	Md. 245 & 251	Maryland	30	35	13	22	21	20	28	169	Delaware & Hudson
90	A. S. C. E.	Carnegie	83	8	1	1		1	76	170	Hocking Valley
90	A. S. C. E.	Maryland	10	7	3	3	4		18	45	Philadelphia & Reading
90	A. S. C. E.	Cambria	2	2	1	1	1		4	11	Philadelphia & Reading
90	C. S.	Illinois	24	16	7			7	15	69	Illinois Central
90	G. N.	Lackawanna	96	96	183	205	56	5	42	683	Great Northern
90	G. N.	Maryland	12	1	3					16	Great Northern
90	G. N.	Cambria	28	8	6	9	13	4		68	Great Northern
85	A. S. C. E.	Maryland	4	1	5			1	11	22	Atlantic Coast Line
85	A. S. C. E.	Carnegie	17	4	9	1			1296	1327	Baltimore & Ohio
85	A. S. C. E.	Maryland	2	7	3	1	2		174	189	Baltimore & Ohio
85	A. S. C. E.	Illinois	9	11	25	34	6	15	974	1074	Illinois Central
85	A. S. C. E.	Illinois	65	12	24	26	2	4	2966	3099	Northern Pacific
85	A. S. C. E.	Lackawanna	37	38	45	50	7		897	1074	Northern Pacific
85	A. S. C. E.	Illinois	77	70	116	88	3	4	1802	2160	Rock Island
85	A. S. C. E.	Carnegie	8	9		5	5	1		28	Southern
85	A. S. C. E.	Maryland	23	11	5	10	8	1		58	Southern
85	C. B. & Q.	Illinois	160	64	131	36	7		275	673	Chicago, Burlington & Quincy
85	C. B. & Q	Col. F. & I.	4	5	4	5	5		155	178	Chicago, Burlington & Quincy
85	P. R. R.	Maryland	4	3		2	7	2	196	214	Pennsylvania Lines East
85	P. R. R.	Maryland	3	4	2	2	1		2	14	New York, Philadelphia & Norfolk
85	P. S.	Cambria	2	3	6	2	2		3	18	Grand Rapids & Indiana
85	P. S.	Maryland	4	3	1	3	1	2		14	New York, Philadelphia & Norfolk
85	P. S.	Carnegie	65	25	91	40		3	29	253	Pennsylvania Lines N. W. System
85	P. S.	Illinois	7	3	9	4				23	Pennsylvania Lines N. W. System
85	P. S.	Cambria	1	1			1		1	4	Pennsylvania Lines N. W. System
85	P. S.	Maryland	4						1	5	Pennsylvania Lines N. W. System
85	P. S.	Carnegie	86	42	83	53	2	4	15	285	Pennsylvania Lines S. W. System
85	P. S.	Illinois	68	10	22	27		3	21	151	Pennsylvania Lines S. W. System
85	P. S.	Cambria	4	2	6	2	3	2	4	23	Pennsylvania Lines East
85	P. S.	Maryland	4	3	5	2	2			16	Pennsylvania Lines East
85	P. S.	Lackawanna	9		3	1			2	15	Pennsylvania Lines East
85	P. S.	Illinois	7	2	11	39			5	64	Vandalia
80	A. S. C. E.	Illinois	36	4	3	3			288	334	Baltimore & Ohio, Chicago Terminal
80	A. S. C. E.	Carnegie	1		2	2	19		46	70	Delaware & Hudson
80	A. S. C. E.	Illinois	49	46	110	189	4		413	811	Lake Shore & Michigan Southern
80	A. S. C. E.	Maryland		3	1	5	5			14	Southern
80	Dudley	Lackawanna	45	37	45	37	12		173	349	New York Central & Hudson River

TABLE No. 7—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN INGOT—CONTINUED

Weight	Section	Manufacturer	Position in Ingot						Unknown	Total	Railroad
			A	B	C	D	E	F, etc.			
					OPEN-HEARTH RAIL						
135	Special	Penna.	10	8	8				8	34	Central of New Jersey
100	A. R. A. "A"	Penna.	1		2	2				5	Central of New Jersey
100	A. R. A. "A"	Bethlehem	30	78	40	37	30	1	7	223	Central of New Jersey
100	A. R. A. "A"	Carnegie		3					1	4	Baltimore & Ohio
100	A. R. A. "A"	Illinois	6	8	2	9	5	3	2	35	Rock Island
100	A. R. A. "B"	Carnegie		2					4	6	Norfolk & Western
100	A. R. A. "B"	Maryland	4	2						6	Norfolk & Western
100	A. R. A. "B"	Illinois	6	2	1				1	10	Norfolk & Western
100	A. R. A. "B"	Bethlehem	3	4	2	1	2	2	10	24	Baltimore & Ohio
100	A. R. A. "B"	Maryland	10	2	2	9	1		5	29	Baltimore & Ohio
100	A. R. A. "B"	Cambria	1	8	1	3	3	3	2	21	Baltimore & Ohio
100	Dudley	Lackawanna	3	3	2				4	12	New York Central & Hudson River
100	Dudley	Bethlehem				1	2			3	New York Central & Hudson River
100	D. L. & W.	Bethlehem	1	2	8					11	Delaware, Lackawanna & Western
100	D. L. & W.	Lackawanna	3						1	4	Delaware, Lackawanna & Western
100	N. Y. N. H. & H.	Penna.	8	1	3	3			10	25	New York, New Haven & Hartford
100	N. Y. N. H. & H.	Bethlehem	16	13	4	9	6	3	14	65	New York, New Haven & Hartford
100	P. S.	Carnegie			1	1	1	1	2	6	Pennsylvania Lines—S. W. System
100	P. S.	Carnegie	5	6	5	4	3	5	6	34	Pennsylvania Lines—N. W. System
100	P. S.	Illinois	5	4	2	2	5	12	16	46	Pennsylvania Lines—N. W. System
100	P. S.	Cambria	8	4	5	1	2	4		24	Pennsylvania Lines—N. W. System
100	P. S.	Penna.	2	2	3	3			3	13	Cumberland Valley
100	P. S.	Bethlehem	5	11	7	25	8		13	69	Pennsylvania Lines East
100	P. S.	Carnegie	3	3	2	3	1		2	14	Pennsylvania Lines East
100	P. S.	Maryland	5	2	3	1			1	12	Pennsylvania Lines East
100	P. S.	Cambria	7	14	14	14	17		10	76	Pennsylvania Lines East
100	P. S.	Lackawanna	15	8	5				4	32	Pennsylvania Lines East
100	P. S.	Penna.	15	7	6	7		1	22	58	Pennsylvania Lines East
100	P. & R.	Penna.	6	4	1	3			5	19	Philadelphia & Reading
90	A. R. A. "A"	Carnegie	2	4	6				5	17	Baltimore & Ohio
90	A. R. A. "A"	Illinois	3	9	15	9	4	6	27	73	Baltimore & Ohio
90	A. R. A. "A"	Bethlehem		4	1		1		1	7	Baltimore & Ohio
90	A. R. A. "A"	Col. F. & I.	6		1	1			1	9	Union Pacific
90	A. R. A. "A"	Illinois	9	6	5	3	1	6		30	Southern Pacific
90	A. R. A. "A"	Col. F. & I.	3	3	1	5		1		13	Southern Pacific

90	A. R. A. "A"	Tenn. C. & I.	1	2	1	1	1	1		7	Southern Pacific
90	A. R. A. "A"	Col. F. & I	2	1	5	14				22	Oregon Short Line
90	A. R. A. "A"	Illinois	51	29	26	30	27	128	22	313	Chicago, Burlington & Quincy
90	A. R. A. "A"	Col. F. & I	15	7	5	13			10	50	Chicago, Burlington & Quincy
90	A. R. A. "A"	Tenn. C. & I.	12	1		1		1	3	18	Illinois Central
90	A. R. A. "A"	Illinois	5	4	2	2	5	2	2	22	Illinois Central
90	A. R. A. "B"	Illinois	2	4	9	10			5	30	Chicago, Indianapolis & Louisville
90	A. R. A. "B"	Illinois	34	30	51	36	22	83	134	390	Northern Pacific
90	A. R. A. "B"	Carnegie	9	8	7	11	5		7	47	Baltimore & Ohio
90	A. R. A. "B"	Maryland	17	5	7	8	1	1	4	43	Baltimore & Ohio
90	A. R. A. "B"	Cambria	12	3	10	7	4	2	3	41	Baltimore & Ohio
90	A. R. A. "B"	Illinois	11	3	4	10		2	2	32	Baltimore & Ohio
90	A. R. A. "B"	Bethlehem	42	40	43	45	63	45	34	312	Baltimore & Ohio
90	A. S. C. E.	Bethlehem	27	16	9	13	8	2	8	83	Delaware & Hudson
90	A. S. C. E.	Bethlehem	35	29	21	25	34	3	132	279	Lehigh Valley
90	A. S. C. E.	Bethlehem		18		5	2	3	5	33	Philadelphia & Reading
90	A. S. C. E.	Penna		1	2	2			2	7	Philadelphia & Reading
90	D. L. & W.	Bethlehem	9	33	23	30	14		168	277	Delaware, Lackawanna & Western
90	D. L. & W	Lackawanna	9	2	2	2			3	18	Delaware, Lackawanna & Western
90	C. S.	Tenn. C. & I	37	59	17	34	17	16	22	202	Illinois Central
90	G. N.	Penna	1	7			1		15	24	Great Northern
90	G. N.	Col. F. & I.	33	3	3	3			6	48	Great Northern
90	G. N.	Bethlehem	64	39	28	17	24	19	29	220	Great Northern
90	G. N.	Illinois	95	77	123	110	129	381	55	970	Great Northern
90	G. N.	Lackawanna	8	1		7			1	17	Great Northern
85	A. S. C. E.	Tenn. C. & I.	1	2	1				1	5	Atlantic Coast Line
85	A. S. C. E.	Tenn. C. & I	4	2	1		1	2	19	29	Illinois Central
85	A. S. C. E.	Carnegie	4		7	3			4	18	Norfolk & Western
85	A. S. C. E.	Cambria		2			1		7	10	Norfolk & Western
85	A. S. C. E.	Penna	2	3		4	2	1	1	13	Norfolk & Western
85	A. S. C. E.	Bethlehem	8	7		2	3		2	22	Norfolk & Western
85	A. S. C. E.	Illinois	10	14	16	28	24	37	16	145	Rock Island
85	A. S. C. E.	Tenn. C. & I	49	11	6	9	3	3	9	90	Southern
85	P. S.	Illinois	3	6	2	3	1	1	4	20	Pennsylvania Lines—S. W. System
85	P. S	Carnegie			2	3		1	2	8	Pennsylvania Lines—N. W. System
85	P. S	Bethlehem	2	1		4	2		4	13	Pennsylvania Lines East
85	P. S	Cambria	7	11	10	7	3	4	3	45	Pennsylvania Lines East
85	P. S	Lackawanna	4		2				5	11	Pennsylvania Lines East
85	P. S.	Penna	4	4	1		1			10	Pennsylvania Lines East
85	P. S.	Illinois	10	4	1	5	2	1	7	30	Vandalia
80	A. S. C. E.	Tenn. C. & I	22	4	4	11	1	8	4	54	Louisville & Nashville
80	A. S. C. E.	Bethlehem	9	1	1	2	2		1	16	New York, New Haven & Hartford
80	A. S. C. E.	Tenn. C. & I	20	2	5	1	3	3	4	38	Southern
80	Dudley	Lackawanna	1			5			1	7	New York Central & Hudson River
75	A. S. C. E.	Tenn. C. & I	4	3						7	Southern

TABLE No. 7—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO POSITION IN INGOT—CONTINUED

Weight	Section	Manufacturer	Position in Ingot A	B	C	D	E	F, etc.	Un-known	Total	Railroad
			FERRO-TITANIUM BESSEMER								
100	A. R. A. "A"	Lackawanna	2	1	....	....	....	....	....	3	Central of New Jersey
100	A. R. A. "B"	Maryland	3	1	....	1	1	....	3	9	Baltimore & Ohio
100	Dudley	Lackawanna	7	6	15	....	....	....	3	31	Boston & Albany
100	Dudley	Lackawanna	69	67	54	....	....	....	11	201	New York Central & Hudson River
90	A. R. A. "B"	Maryland	11	3	3	5	5	....	....	27	Baltimore & Ohio
90	A. R. A. "B"	Lackawanna	1	3	1	7	....	....	7	19	Northern Pacific
90	A. S. C. E	Lackawanna	2	....	3	4	....	....	41	50	Philadelphia & Reading
90	A. S. C. E	Lackawanna	10	5	9	12	3	4	52	95	Lehigh Valley
90	G. N	Lackawanna	14	....	4	3	....	2	1	24	Great Northern
80	Dudley	Lackawanna	131	96	104	135	1	....	23	490	New York Central & Hudson River
			FERRO-TITANIUM OPEN-HEARTH								
110	L. V	Bethlehem	8	2	6	8	....	....	2	26	Lehigh Valley
100	A. R. A. "A"	Bethlehem	3	6	5	5	5	....	1	25	Lehigh Valley
100	A. R. A. "A"	Lackawanna	1	2	1	....	....	....	1	5	Lehigh Valley
100	A. R. A. "A"	Carnegie	....	....	1	....	....	....	1	2	Lehigh Valley
100	D. L. & W	Bethlehem	2	4	3	1	....	....	....	10	Delaware, Lackawanna & Western
90	A. R. A. "B"	Maryland	11	2	....	....	....	....	1	14	Baltimore & Ohio
90	A. S. C. E	Carnegie	....	....	1	1	1	1	5	9	Lehigh Valley
90	A. S. C. E	Lackawanna	2	....	1	1	1	1	....	6	Lehigh Valley
90	A. S. C. E	Bethlehem	4	12	13	11	10	7	25	82	Lehigh Valley
			ELECTRIC PROCESS								
90	A. R. A. "A"	Illinois	2	3	3	1	....	....	1	10	Union Pacific
			D. L. & W. R. R. "SPECIAL PREMIUM" OPEN-HEARTH								
100	D. L. & W	Lackawanna	3	7	2	....	....	....	2	14	Delaware, Lackawanna & Western
			NICKEL CHROME—BESSEMER RAIL								
100	A. R. A. "A"	Maryland	....	1	1	2	....	....	3	7	Central of New Jersey

TABLE No 8 GENERAL SUMMARY, BY SECTIONS, OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT

(Percentage based on known failures.)

Weight	Section	Manufacturer	Position in Ingot A	B	C	D	E	F, etc.	Total Known	Unknown	Total
			BESSEMER RAIL								
100	A. R. A. "A"	Various	5 5.5%	64 70.3%	18 19.8%	2 2.2%		2 2.2%	91 100%	18	109
100	A. R. A. "B"	Various	122 46.1%	52 19.6%	44 16.6%	26 9.8%	20 7.5%	1 .37%	265 100%	55	320
100	A. S. C. E.	Various	82 34.4%	62 25.9%	84 35.1%	6 2.5%	5 2.1%		239 100%	1,529	1,768
100	Dudley	Lackawanna	79 36.4%	79 36.4%	50 23.1%	5 2.2%	2 .9%		215 100%	605	820
100	P. & R.	Various	12 57.2%	3 14.3%	4 19.0%	2 9.5%			21 100%		21
100	P. R. R.	Various		13 40.6%	9 28.2%	2 6.2%	7 21.9%	1 3.1%	32 100%	300	332
100	P. S.	Various	65 23.0%	99 35.2%	64 22.7%	36 12.8%	14 4.9%	3 1.2%	281 100%	68	349
Total all 100-lb.			365 32%	372 32.5%	273 23.8%	79 7%	48 4.1%	7 .61%	1,144 100%	2,575	3,719
80	Dudley	Lackawanna	45 25.6%	37 21%	45 25.6%	37 21%	12 6.8%		176 100%	173	349
80	A. S. C. E.	Various	86 17.8%	53 11%	116 24.1%	199 41.3%	28 5.8%		482 100%	747	1,229
Total all 80-lb.			131 20%	90 13.7%	161 24.5%	236 35.8%	40 6%		658 100%	920	1,578
90	A. R. A. "A"	Various	172 26.6%	82 12.7%	220 34.4%	148 22.9%	16 2.5%	6 .9%	644 100%	476	1120
90	A. R. A. "B"	Various	388 39.1%	136 13.2%	266 26.0%	113 11.4%	39 3.9%	45 4.5%	987 100%	106	1,093
90	Md. 245 & 251	Maryland	30 21.3%	35 24.8%	13 9.2%	22 15.6%	21 14.9%	20 14.2%	141 100%	28	169
90	A. S. C. E.	Various	95 74.2%	17 13.3%	5 3.9%	5 3.9%	5 3.9%	1 .8%	128 100%	98	226
90	C. S.	Illinois	24 44.4%	16 29.6%	7 13%			7 13%	54 100%	15	69
90	G. N.	Various	136 18.7%	105 14.5%	192 26.5%	214 29.5%	69 9.5%	9 1.8%	725 100%	42	767
Total all 90-lb.			845 31.5%	391 14.6%	703 26.7%	492 18.3%	150 5.6%	88 3.3%	2,679 100%	765	3,444

TABLE No. 8—GENERAL SUMMARY, BY SECTIONS, OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT—CONTINUED

(Percentage based on known failures.)

Weight	Section	Manufacturer	Position in Ingot: A	B	C	D	E	F, etc.	Total Known	Unknown	Total
			BESSEMER RAIL								
85	A. S. C. E.	Various	242 26.6%	163 17.9%	232 25.5%	215 23.6%	33 3.6%	26 2.8%	911 100%	8,120	9,031
85	C. B. & Q.	Various	164 38.9%	69 16.4%	135 32%	41 9.8%	12 2.9%		421 100%	430	851
85	P. R. R.	Maryland	7 23.3%	7 23.3%	2 6.7%	4 13.3%	8 26.7%	2 6.7%	30 100%	198	228
85	P. S.	Various	261 33.1%	94 11.9%	237 30%	173 21.9%	11 1.4%	14 1.7%	790 100%	81	871
Total all 85-lb			674 31.2%	333 15.4%	606 28.1%	433 20.2%	64 3.1%	42 2%	2,152 100%	8,829	10,981
			OPEN-HEARTH RAIL								
135	Special	Penna.	10 38.4%	8 30.8%	8 30.8%				26 100%	8	34
100	A. R. A. "A"	Various	37 14.4%	89 34.7%	44 17.1%	48 18.7%	35 13.6%	4 1.5%	257 100%	10	267
100	A. R. A. "B"	Various	24 32.4%	20 27.2%	6 8.1%	13 17.5%	6 8.1%	5 6.7%	74 100%	22	96
100	Dudley	Various	3 27.3%	3 27.3%	2 18.2%	1 9%	2 18.2%		11 100%	4	15
100	D. L. & W.	Various	4 28.6%	2 14.3%	8 57.1%				14 100%	1	15
100	N.Y.N.H.&H.	Various	24 36.3%	14 21.1%	7 10.7%	12 18.2%	6 9.1%	3 4.6%	66 100%	24	90
100	P. S.	Various	70 22.9%	61 20%	53 17.4%	61 20%	37 12.1%	23 7.6%	305 100%	79	384
100	P. & R.	Penna.	6 42.9%	4 28.6%	1 7.1%	3 21.4%			14 100%	5	19
Total all 100-lb			168 22.6%	193 26.2%	121 16.3%	138 18.6%	86 11.6%	35 4.7%	741 100%	145	886

90	A. R. A. "A"	Various	106 21.4%	70 13.7%	[illegible] 13.3%	79 15.5%	39 7.7%	145 28.4%	510 100%	71	581
90	A. R. A. "B"	Various	127 17.9%	93 13.2%	131 18.6%	127 18.1%	95 13.5%	133 18.7%	706 100%	189	895
90	A. S. C. E.	Various	62 24.3%	64 25.2%	32 12.5%	45 17.6%	44 17.3%	8 3.1%	255 100%	147	402
90	D. L. & W.	Various	18 14.5%	35 28.2%	25 20.2%	32 25.8%	14 11.3%	......	124 100%	171	295
90	C. S.	Tenn. C. & I.	37 20.6%	59 32.9%	17 9.4%	34 18.8%	17 9.4%	16 8.9%	180 100%	22	202
90	G. N.	Various	201 17.9%	127 9.9%	154 13.2%	137 11.6%	154 13.2%	400 34%	1,173 100	106	1,279
Total all 90-lb.			554 18.8%	448 15.2%	427 14.5%	454 15.4%	363 12.3%	702 23.8%	2,948 100%	706	3,654
85	A. S. C. E.	Various	78 28.6%	41 15%	31 11.3%	46 16.9%	34 12.4%	43 15.8%	273 100%	59	332
85	P. S.	Various	30 26.8%	26 23.2%	18 16.1%	22 19.6%	9 8%	7 6.3%	112 100%	25	137
Total all 85-lb.			108 28.1%	67 17.1%	49 12.6%	68 17.6%	43 11.6%	50 13%	385 100%	84	469
80	A. S. C. E.	Various	51 51.5%	7 7.1%	10 10.1%	14 14.2%	6 6%	11 11.1%	99 100%	9	108
80	Dudley	Lackawanna	1 16.6%	......	......	5 83.4%	......	......	6 100%	1	7
Total all 80-lb.			52 49.6%	7 6.6%	10 9.5%	19 18.1%	6 5.7%	11 10.5%	105 100	10	115
75	A. S. C. E.	Tenn. C. & I.	4 57.2%	3 42.8%	......	......	......	......	7 100%	......	7

NICKEL CHROME

100	A. S. C. E.	Maryland	......	1 25%	1 25%	2 50%	......	......	4 100%	3	7

TABLE No. 8—GENERAL SUMMARY, BY SECTIONS, OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT—CONTINUED

(Percentage based on known failures.)

Weight	Section	Manufacturer	Position in Ingot A	B	C	D	E	F, etc.	Total Known	Unknown	Total
			FERRO-TITANIUM BESSEMER RAIL								
100	A. R. A. "A"	Lackawanna	2 66.7%	1 33.3%					3 100%		3
100	A. R. A. "B"	Maryland	3 49.9%	1 16.7%		1 16.7%	1 16.7%		6 100%	3	9
100	Dudley	Lackawanna	76 34.8%	73 33.5%	69 31.7%				218 100%	14	232
Total all 100-lb.			81 35.6%	75 33%	69 30.5%	1 .45%	1 .45%		227 100%	17	244
90	A. R. A. "B"	Various	12 30.7%	6 15.4%	4 10.2%	12 30.8%	5 12.9%		39 100%	7	46
90	A. S. C. E.	Lackawanna	12 23.1%	5 9.6%	12 23.1%	16 30.7%	3 5.8%	4 7.7%	52 100%	93	145
90	G. N.	Lackawanna	14 60.9%		4 7.4%	3 13%		2 8.7%	23 100%	1	24
Total all 90-lb.			38 33.4%	11 9.6%	20 17.5%	31 27.2%	8 7%	6 5.3%	114 100%	101	215
80	Dudley	Lackawanna	131 28.1%	96 20.5%	104 22.3%	135 28.9%	1 .2%		467 100%	23	490
			FERRO-TITANIUM OPEN-HEARTH								
110	L. V.	Bethlehem	8 33.3%	2 8.3%	6 25.1%	8 33.3%			24 100%	2	26
100	A. R. A. "A"	Various	4 13.8%	8 27.6%	7 24.1%	5 17.2%	5 17.2%		29 100%	3	32
100	D. L. & W.	Bethlehem	2 20%	4 40%	3 30%	1 10%			10 100%		10
Total 110 and 100-lb.			14 22.2%	14 22.2%	16 25.5%	14 22.2%	5 7.9%		63 100%	5	68

90	A. R. A. "B".	Maryland	11 84.6%	2 15.4%	....	....	....	....	13 100%	1	14
90	A. S. C. E.	Various	6 8.9%	12 17.9%	15 22.4%	13 19.5%	12 17.9%	9 13.4%	67 100%	30	97
Total all 90-lb.			37 20.3%	40 21.9%	41 22.5%	33 18.2%	22 12.2%	9 4.9%	182 100%	39	221

ELECTRIC PROCESS

90	A. R. A. "A".	Illinois	2 22.2%	3 33.4%	3 33.4%	1 11%	....	....	9 100%	1	10

D. L. & W. R. R. SPECIAL PREMIUM—OPEN-HEARTH

100	D. L. & W.	Lackawanna	3 25%	7 58.3%	2 16.7%	....	....	....	12 100%	2	14

TABLE No. 9—GENERAL SUMMARY, BY MANUFACTURERS, OF NUMBER OF RAIL FAILURES CLASSIFIED ACCORDING TO POSITION IN INGOT

(Percentage based on known failures)

Manufacturer	Steel	Position in Ingot						Total known	Unknown	Total
		A	B	C	D	E	F, etc.			
Cambria	Bessemer	113	64	45	64	56	17	359	38	397
		31.6%	17.8%	12.5%	17.8%	15.6%	4.7%	100%		
Carnegie	Bessemer	636	364	552	218	46	34	1,850	1,671	3,521
		34.4%	19.7%	29.8%	11.8%	2.5%	1.8%	100%		
Colo. F. & I	Bessemer	4	5	4	5	5		23	155	178
		17.4%	21.7%	17.4%	21.7%	21.8%		100%		
Illinois	Bessemer	695	364	689	555	39	38	2,380	8,214	10,594
		29.2%	15.3 %	29%	23.3%	1.6%	1.6%	100%		
Lackawanna	Bessemer	304	263	363	322	82	19	1,353	2,074	3,427
		22.5%	19.4%	26.8%	23.8%	6.1%	1.4%	100%		
Maryland	Bessemer	263	126	90	86	74	29	668	937	1,605
		39.4%	18.8%	13.5%	12.9%	11.1%	4.3%	100%		
Total all Bessemer		2,015	1,186	1,743	1,250	302	137	6,633	13,089	19,722
		30.2%	17.8%	26.2%	18.7%	4.5%	2.6%	100%		
Bethlehem	Open-Hearth	251	296	187	216	201	78	1,229	428	1,657
		20.4%	24.1%	15.2%	17.6%	16.4%	6.3%	100%		
Cambria	Open-Hearth	35	42	40	32	30	13	192	25	217
		18.3%	21.8%	20.8%	16.7%	15.6%	6.8%	100%		
Carnegie	Open-Hearth	23	26	30	25	10	7	121	33	154
		19%	21.5%	24.8%	20.7%	8.3%	5.7%	100%		
Colo. F. & I	Open-Hearth	59	14	15	36		1	125	17	142
		47.2%	11.2%	12%	28.8%		0.8%	100%		
Illinois	Open-Hearth	250	200	259	257	225	662	1,853	293	2,146
		13.5%	10.8%	14.0%	13.9%	12.1%	35.7%	100%		
Lackawanna	Open-Hearth	43	14	11	1			82	19	101
		52.4%	17.1%	13.4%	17.1%			100%		
Maryland	Open-Hearth	36	11	12	18	2	1	80	10	90
		45%	13.7%	15%	22.5%	2.5%	1.3%	100%		
Penna	Open-Hearth	49	37	26	24	4	2	142	66	208
		34.6%	26%	18.3%	16.9%	2.8%	1.4%	100%		
Tenn. C. & I	Open Hearth	150	86	35	57	26	34	388	62	450
		38.6%	22.2%	9.0%	14.7%	6.8%	8.7%	100%		
Total all Open-Hearth		896	726	615	679	498	796	4,212	953	5,165
		21.3%	17.3%	14.6%	16.1%	11.8%	18.9%	100%		

Lackawanna	Ferro-Titanium Bessemer	236 30.4%	178 23.0%	190 24.5%	161 20.8%	4 0.5%	6 0.8%	775 100%	138	913
Maryland	Ferro-Titanium Bessemer	14 42.4%	4 12.1%	3 9.1%	6 18.2%	6 18.2%	....	33 100%	3	36
Total Ferro-Titanium Bessemer		250 31%	182 22.6%	193 23.9%	167 20.6%	10 1.2%	6 0.7%	808 100%	141	949
Bethlehem	Ferro-Titanium O. H.	17 14.8%	24 20.9%	27 23.4%	25 21.8%	15 13.0%	7 6.1%	115 100%	28	143
Carnegie	Ferro-Titanium O. H.	....	....	2 40%	1 20%	1 20%	1 20%	5 100%	6	11
Maryland	Ferro-Titanium O. H.	11 84.6%	2 15.4%	....	....	....	....	13 100%	1	14
Lackawanna	Ferro-Titanium O. H.	3 30%	2 20%	2 20%	1 10%	1 10%	1 10%	10 100%	1	11
Total Ferro-Titanium O. H.		31 21.6%	28 19.6%	31 21.7%	27 18.9%	17 11.9%	9 6.3%	143 100%	36	179
Maryland	Nickel Chrome Bessemer	....	1 25%	1 25%	2 50%	....	....	4 100%	3	7
Lackawanna	D. L. & W. Special Premium O. H.	3 25%	7 58.3%	2 16.7%	....	....	....	12 100%	2	14
Illinois	Electric Process	2 22.3%	3 33.3%	3 33.3%	1 11.1%	....	....	9 100%	1	10

DIAGRAMS NO. 1 AND NO 2—COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL, BESSEMER AND OPEN-HEARTH STEEL.

No. 1—Bessemer Steel.—The 76 and 79-lb. sections should be disregarded on account of the small tonnage.

The rate of failure of the 85-lb., 90-lb. and 100-lb. sections is greater than that of the lighter sections, including the 95-lb. Better results would naturally be expected from the heavier sections. Some factor other than design and weight is clearly responsible for increased number of failures.

No. 2—Open-Hearth Steel.—The highest rate of failure this year is found in the 90-lb. rail, as is also true of the Bessemer steel. The 80-lb. rail, which had the highest rate last year, has this year dropped back to about the same rate as in 1910.

The general average (all weights) is lower for the Open-Hearth than for the Bessemer, being 24.0 per 10,000 tons laid, as against 52.0 for the Bessemer.

DIAGRAMS NOS. 3 AND 4—COMPARISON BETWEEN DIFFERENT SECTIONS, BESSEMER AND OPEN-HEARTH STEEL.

Diagram No. 3, Bessemer Steel.—There is a wide difference in results between different sections of same weight. For instance, in the 100-lb., failures range from 4.6 (per 10,000 tons) to 92.9. Note, however, that the A. R. A. "B" and P. S. sections range close together, having 36.7 and 33.7, respectively.

Diagram No. 4, Open-Hearth Steel.—The same lack of uniformity in rate of failures for different sections of the same weight is found.

Comparing Diagrams 3 and 4, we note that the 100-lb. A. S. C. E. compares favorably with the other rails in the Open-Hearth steel and badly with the other rails in the Bessemer steel. Why should not its relation to the other sections be independent of the kind of steel?

It is also peculiar that the N. Y. N. H. & H. section 100-lb. rail shows 24.0 failures (per 10,000 tons) in the Open-Hearth and only 4.6 in the Bessemer.

DIAGRAMS NOS. 5 AND 6—COMPARISON BETWEEN DIFFERENT MANUFACTURERS, BESSEMER AND OPEN-HEARTH STEEL.

These diagrams show the same lack of uniformity of performance as is brought out in all the data considered heretofore. The different weights of rail do not show the same results when rolled by different mills, nor does the rail from the different mills stand in the same order of superiority in the Bessemer steel as in the Open-Hearth.

For instance, the 100-lb. Bessemer rail rolled by seven mills is in second place once, in third place three times, in fourth place twice and in fifth place once.

Of the first five mills in order of merit in the Bessemer steel, only two rank among the first five in the Open-Hearth steel; i. e., Pennsylvania ranks 1 in Bessemer and 5 in Open-Hearth; and Colorado Fuel & Iron ranks 5 in Bessemer and 1 in Open-Hearth. If we take the first *four* mills in order of merit, we have none appearing in both the Bessemer and Open-Hearth.

It is peculiar that while there is this general lack of uniformity, that out of 10 mills rolling 90-lb. Open-Hearth rail, it in 9 cases shows the worst results and in the tenth case stands in third place.

In the Bessemer steel, out of 8 mills rolling 90-lb. rail, it shows the worst results in 3 cases, the best results in 2 cases, stands second in 2 cases and third in 1 case.

DIAGRAMS NOS. 7 AND 8—COMPARISON BETWEEN VARIOUS WEIGHTS OF RAIL FOR FOUR YEARS.

Diagram 7. Bessemer Steel.
Diagram 8. Open-Hearth Steel.

These diagrams show in general an increase in the rate of failure during 1912. The 95-lb. and 75-lb. Bessemer and 80-lb. Open-Hearth are the exceptions to this.

DIAGRAMS NO. 9 (BESSEMER) AND NO. 10 (OPEN-HEARTH).

These diagrams give in graphic form all the detail information shown on Sheets 1 to 76 of the statistics, except the classification as to kind of failures.

They afford a ready method of referring to the details, and should be used in connection with the other diagrams and summaries.

These are new diagrams, prepared for the first time for use with this report.

DIAGRAMS NO. 11 (BESSEMER), NO. 12 (OPEN-HEARTH) AND NO. 13 (COMBINED BESSEMER AND OPEN-HEARTH).

These are new diagrams, prepared for the first time for this report, and show the rate of failure of rail on each railroad, irrespective of weight or section of rail used.

Diagram 13 is probably the most interesting, as it shows the total failures for each road.

A number of roads report no failures, i. e.:

Baltimore, Chesapeake & Atlantic..........3,175 tons..85-lb. rail.
Cincinnati Northern ....3,600 tons..80-lb. rail.
Colorado Midland ....3,000 tons..80-lb. rail.
Houston East & West Texas.............2,306 tons..75-lb. rail.
St. Louis, San Francisco & Texas.........6,276 tons..75-lb. rail.
Toledo, Peoria & Western................2,999 tons..85 and 80-lb. rail.

Nine roads show more than 100 failures per 10,000 tons as follows:

Railroad	Failures per 10,000 Tons	Tons Rail Laid	Kind of Rail Used
B. & O. C. T.	169.6	19,684	80 A. S. C. E.
Erie	166.3	173,963	100, 90, 80 A. S. C. E.
Central Vermont	138.8	26,946	80 A. S. C. E.
Northern Pacific	128.1	411,397	100, 90, A. R. A. "B" 85 A. S. C. E., 72 N. P.
Rutland	124.4	4,500	80 Dudley
Great Northern	120.9	177,453	90 G. N.
Chicago, Indianapolis & Louisville	115.6	60,859	90 A. R. A. "B", 75 A. S. C. E.
C. C. C. & St. L.	115.0	267,035	90, 80 A. S. C. E.
Erie & Jersey	110.9	10,903	90 A. S. C. E.

An interesting study is obtained by selecting three groups of five roads each, as follows:

Railroad	Failures per 10,000 Tons	Tons Rail Laid	Kind of Rail Used
1 Combined Fast Passenger and Heavy Freight Roads.			
B. & O.	93.4	499,826	100 & 90 A. R. A. "A & B", 100 & 85 A. S. C. E.
L. S. & M. S.	79.4	442,383	100 & 80 A. S. C. E.
Penna Lines, West	51.3	837,130	100 A. R. A. "A", 100 & 85 P. S. and A. S. C. E. 85 P. R. R.
Penna Lines, East	26.7	1,229,440	100 & 85 A. S. C. E., P. S. & P. R. R. 80 A. S. C. E.
N. Y. C. & H. R.	12.1	418,194	100 & 80 Dudley.
2 Roads Principally of Fast Passenger Traffic			
Boston & Maine	57.5	207,699	100 Dudley & N. Y. N. H. & H., 85, 79, 76 A.S.C.E 75 B. & M.
Boston & Albany	16.9	106,821	100 Dudley, 95 B. & A.
N. Y. N. H. & H.	15.1	120,967	100, 80, 78 N. Y. N. H. & H., 80 A. S. C. E.
Long Island	12.2	71,472	100, 90, 85, 80 A. S. C. E.
Atlantic Coast Line	2.3	180,620	85, 80 A. S. C. E.
3 Roads Principally of Heavy Freight Traffic			
Erie	166.3	173,963	100, 90, 80 A. S. C. E.
Lehigh Valley	72.4	143,745	90 A. S. C. E.
Bessemer & Lake Erie	62.3	85,376	100, A. R. A. "B" and A. S. C. E.
D. L. & W.	31.0	103,681	100, 90 D. L. & W.
Norfolk & Western	5.5	323,223	100 A. R. A. "B", 85, 75 A. S. C. E.

RECORD OF COMPARATIVE WEAR OF SPECIAL RAIL.

BALTIMORE & OHIO RAILROAD.

The following tests were reported as completed during the past year:

Comparison between Bethlehem Open-Hearth and Cambria Bessemer, both 90-lb. A. R. A. "B" on 7-deg. .05-min. curve at Bloomington, W. Va. Both laid April 4, 1909. Open-Hearth removed after 38 months, and Bessemer removed after 23 months' wear.

Area abraded; Open-Hearth: High Rail, 0.839 sq. in.; Low Rail, 0.630 sq. in.

Area abraded; Bessemer: High Rail, 1.196 sq. in.; Low Rail, 0.970 sq. in.

Comparison between Maryland Open-Hearth 90-lb. A. R. A. "B" and Pennsylvania Open-Hearth 85-lb. A. S. C. E., on No. 76 Fill, Cheat River Grade. Both laid November 22, 1910, and removed after 21 months' wear.

Area abraded; Maryland 90-lb. A. R. A. "B": High Rail, 0.757 sq. in.; Low Rail, 1.001 sq. in.

Area abraded; Pennsylvania 85-lb. A. S. C. E.: High Rail, 0.312 sq. in.; Low Rail, 0.296 sq. in.

A number of tests are reported as in progress, the most important of which are given below.

At Snow Creek Curve (8 deg. 42 min.) on Cumberland Division a test of Bessemer Titanium rail is being made. After 2 years' wear the results are as follows:

Kind of Steel	Chemical Composition					Area abraded	
	C.	P.	Mn.	Si.	Titanium Alloy	High	Low
Maryland 90-lb. A. R. A. "B" Bessemer Titanium Laid Aug. 6, 1910	0.45 to 0.55	Not to exceed 0.10	0.80 to 1.20	0.05 to 0.20	0.3 0.5 1.0 1.5	0.357 .362 .347 .360	0.229 .254 .269 .207
AT MARRIETTSVILLE, BALTIMORE DIV., 9° 45′ CURVE, LAID JUNE 24, 1912.							
Maryland-100-lb. A. R. A. "B" Bessemer........................	.46-.56	0.10	.80-1.20	.05-.20	....	.170	.075
Carnegie -100-lb. A. R. A. "B" Open-Hearth....................	.70-.80	0.04	.75-1.00	.05-.20	....	.104	.074
Maryland-100-lb. A. R. A. "B" Bess. Titan.....................	.46-.56	0.10	.80-1.20	.05-.20	1.00	.199	.111
AT LESMALINSTON, CUMBERLAND DIV., 5° 30′ CURVE, LAID MAY 18, 1911.							
Illinois-100-lb. A. R. A. "B" Open-Hearth..........................	.70-.80	0.04	.75-1.00	.05-.20	....	.158	.139
Illinois-100-lb. A. R. A. "B" Bessemer..........................	.46-.56	0.10	.80-1.20	.05-.20	....	.229	.147
Lackawanna-90-lb. A. R. A. "B" Bess. Titan.....................	.46-.56	0.10	.80-1.20	.05-.20	.3	.197	.105
Maryland-90-lb. A. R. A. "B" Bessemer........................	.46-.56	0.10	.80-1.20	.05-.20	....	.188	....
AT THORNTON, WEST VIRGINIA, TO TEST RAIL FROM DIFFERENT SIZE INGOTS ALL 100-lb. A. R. A.-B. ILLINOIS BESSEMER RAIL ON 5° 48′ CURVE, LAID OCTOBER 31, 1911.							
Ingot A-15"x15"x60"..............	.49	.097	.90	.074	....	.347	.155
Ingot B-18"x18"x60"..............	.49	.097	.90	.074	....	.314	.167
Ingot C-20"x24' x60"..............	.49	.097	.90	.074	....	.272	.129
Ingot D-25"x30"x60"..............	.49	.097	.90	.074	....	.262	.117

BOSTON & ALBANY.

Lackawanna Dudley 100-lb. Bessemer rail is being compared with similar rail containing .02 per cent. Ferro-Titanium. After four years, the area abraded, in square inches, is 0.138 for the Ferro-Titanium and 0.127 for the plain Bessemer.

BOSTON & MAINE.

The following test is in progress at Athol. The rail is all 85-lb. A. S. C. E., laid in September and October, 1910.

Kind of Rail	Length of service	Chemical Composition C.	P.	Mn.	Si.	F. T.	Chro.	Ni.	% of Head Abraded
Bethlehem Open-Hearth....	27 mo.	.67	.025	.87	.175	......	......	......	6.46
Maryland Open-Hearth.....	27 mo.	.68	.016	.75-.80	.067	......	.51	.51	4.99
Lackawanna Open-Hearth...	27 mo.	.88	.017	.90	.144	.15	......	......	2.83
Lackawanna Open-Hearth...	27 mo.	.85	.021	.90	.144	.20	......	......	3.26
Lackawanna Open-Hearth...	27 mo.	.71	.019	.85	.118	......	......	......	4.19
Maryland Bessemer.........	26 mo.	.53	.059	1.02	.075	......	.19	.19	5.39
Lackawanna Bessemer F. T.	26 mo.	.53	.059	1.02	.075	......	......	......	4.33

The Ferro-Titanium rail makes a very favorable showing.

CHICAGO GREAT WESTERN.

A comparative test of Bessemer, Bessemer Ferro-Titanium and Open-Hearth rail is being made, all 85-lb. A. S. C. E. section; chemical composition is not given. After 26 months' service the Ferro-Titanium shows an average area abraded of .079 sq. in.; the Bessemer, .056 sq. in., and the Open-Hearth, .075 sq. in.

DELAWARE, LACKAWANNA & WESTERN.

Four tests are being made as follows:

(1) Comparison of Open-Hearth and Open-Hearth Chrome Nickel. The Open-Hearth Chrome Nickel does not compare favorably with the other.

(2) Comparison of Open-Hearth, Open-Hearth Ferro-Titanium and Open-Hearth "Special Premium." The best showing has been made by the ordinary Open-Hearth.

(3) Comparison of Open-Hearth Ferro-Titanium and Open-Hearth "Special Premium." The Ferro-Titanium makes the best showing.

(4) Comparison of Open-Hearth Ferro-Titanium and ordinary Open-Hearth. The Ferro-Titanium makes the best showing.

LAKE SHORE & MICHIGAN SOUTHERN.

A. S. C. E. 100-lb. Ferro-Titanium compared with Bessemer 100-lb. A. S. C. E. The Ferro-Titanium shows more abrasion than the ordinary Bessemer.

P. R. R. 85-lb. Manganese compared with A. S. C. E. 100-lb. Ferro-Titanium: Average area abraded, Manganese, 0.30 sq. in.; average area abraded, Ferro-Titanium, 1.07 sq. in.

A. S. C. E. 80-lb. Electric compared with A. S. C. E. 100-lb. Bessemer. The Electric rail shows less abrasion than the Bessemer rail.

NORFOLK & WESTERN.

Comparison between Manganese 85-lb. A. S. C. E. and Carnegie Bessemer and Bethlehem Open-Hearth 85-lb. A. S. C. E.

The Manganese rail contains .77 Carbon, .06 Phosphorus and 9.93 Manganese.

The first test was started on April 1, 1909. After 18½ months the Carnegie rail was removed and replaced by Bethlehem, which is still in service.

The areas abraded are as follows:

Carnegie Bessemer Rail, 18½ months' service, 0.825 sq. in.

Bethlehem Open-Hearth Rail, 27½ months' service, 0.270 sq. in.

Manganese Rail, 46 months' service, 0.350 sq. in.

The second test was started January 30, 1912, and the areas abraded are as follows:

Bethlehem Open-Hearth, 12 months' service, 0.19 sq. in.

Manganese Rail, 12 months' service, 0.08 sq. in.

Three of the Manganese rails in the first test broke. No definite cause was found, but the Manganese Steel Company state it to be improper heat treatment at the mill.

PENNSLYVANIA RAILROAD, LINES EAST.

Two comparative tests are reported:

1. P. S. 100-lb. Pennsylvania Steel Company Nickel Chrome compared with Cambria Open-Hearth.

2. P. S. 100-lb. Maryland Nickel Chrome compared with Manard and Open-Hearth.

The results are shown below.

Kind of Steel	Chemical Composition							Length of service	Area Abraded
	C.	P.	Mn.	Si.	S.	Ni.	Cr.		
Penna. Nickel Chrome......	.45	.063	.84	.079	.066	.94	.33	13 mo.	.22 sq. in.
Cambria Open-Hearth......	.70	.033	.69	.058	.038	......	......	13 mo.	.34 sq. in.
Maryland Nickel Chrome...	.45	.063	.84	.079	.066	.94	.33	4 mo.	1.00 sq. in.
Manard......................	1.40	......	13.21	......	......	......	......	4 mo.	.075 sq. in.
Open-Hearth................	.73	.019	.75	.115	.029	......	......	4 mo.	.52 sq. in.

In the first test the Nickel Chrome makes a better showing than the Open-Hearth.

In the second test, the Manard rail makes the best showing, but the Nickel Chrome does not show as well as the Open-Hearth.

PENNSLYVANIA LINES, WEST OF PITTSBURGH, NORTHWEST SYSTEM.

The test of High Silicon rail reported last year is still in progress. This is Open-Hearth rail containing a higher percentage of Silicon than usual and is being compared with ordinary Open-Hearth of the same rolling.

The results are shown below.

Kind of Steel	Chemical Composition					Length of service	Area Abraded
	C.	P.	Mn.	Si.	S.		
Open-Hearth.............	.63-.72	.020-.039	.60-.80	.14-.20	.034-.090	14 mo.	0.159 sq. in.
High Silicon.............	.72	.029	.80	.31	.039	14 mo.	0.152 sq. in.

The difference is too small to be considered. Tests of Mayari and Electric process rail are also being started, but no reports are as yet available.

PENNSYLVANIA LINES, WEST OF PITTSBURGH, SOUTHWEST SYSTEM.

Tests are being made at two points, i. e.:
(1) On Ohio Connecting Railway, and
(2) At Holliday's Cove.
Results are given below:

Kind of Steel	Length of service	Chemical Composition							Area Abraded, Sq. In.	
		C.	P.	Mn.	Si.	S.	Ni.	Chro.	Actual	Per 10,000,000 Tons
Ohio Connecting Railway, 85-lb. P. S., except Items 2 and 3, which are 85-lb. A. S. C. E.										
1. Penna. Mayari O.H.	20 mo.	.805	.022	.87	.17	.035	.97	.21	.595	.09
2. Carnegie, Bessemer	3 mo.	.55	.07	1.05	.13	....	....	.....	.672	....
3. Carnegie, Bessemer	10 mo.	.51	.093	.88	.103	.045	....	.....	.68	.18
4. Maryland Bessemer	4 mo.	.50	.077	.95	.091	.056	....	.....	.45	.39
5. Cambria, Bessemer	7 mo.	.52	.096	.90	.085	.090	....	.....	.645	.23
6. Illinois, O. H	11 mo.	.65	.032	.69	.14	.041	....	.....	.772	.22
7. Carnegie, O. H.	9 mo.	.75	.03	.80	.12	....	....	.....	.68	....
8. Illinois, O. H	9 mo.	.75	.03	.80	.12	....	....	.....	.72	....
Holliday's Cove, 100-lb. P. S., except Item 2, which is 100-lb. A. S. C. E.										
1. Illinois, Electric	2 mo.	.61	.021	.74	.191	.035	....	.....	.06	....
2. Carnegie, Bessemer	5 yr.	.51	.096	.85	.103	.043	....	.....	.70	....
3. Carnegie, O. H.	2 mo.	.67	.030	.67	.142	.034	....	.....	.055	....

ROCK ISLAND LINES.

Comparative tests of Ferro-Titanium, Electric process and ordinary Open-Hearth rails, all 100-lb. A. R. A. "A," are being made. All are of standard composition. After 17 months the results are as follows:

	Area Abraded, Sq. In.		
	Ferro-Titanium	Electric	Open-Hearth
On 0° 50′ Curve	.012	.008	.075
On 1° 00′ Curve	.017	.137	.063
On Tangent	.012	.028	.078
Average	.014	.058	.075

The Ferro-Titanium is also being tried at two other points, viz.:
On 1-deg. 20-min. curve, area abraded, .030 sq. in.
On 1-deg. 30-min. curve, area abraded, .010 sq. in.

DEDUCTIONS.

(1) The statistics are for all roads and do not take into consideration differences in wheel-loads, speed or tonnage over the rails. The averages are derived from a study of large quantities of rail, and may be considered as fairly representing the performance of the product of the different mills.

(2) In studying these statistics, small lots of rail should be ignored, as the results are misleading. In future reports, all individual lots of less than 2,000 tons should be omitted, and all rail of which a total of less than 10,000 tons is reported should be excluded from the summaries, except in cases of special alloys or sections, or of rails used for tests.

(3) The wide variation in results must be due, to a large extent, to a lack of uniformity in the performance of different mills, and also to a lack of uniformity in the product of any individual mill.

(4) The average performance of the heavy sections (85-lb. to 100-lb.) is not so good as that of the lighter sections (72-lb. to 80-lb.).

(5) The average rate of failure of the Open-Hearth rail is lower than that of the Bessemer, although both are higher than last year. The thought expressed in last year's report, that possibly, as its age increases, the rate of failure of the Open-Hearth rail will increase so as to approach that of the Bessemer rail, is not corroborated by this year's figures.

The rate of failure of the Open-Hearth rail was, in 1912, 22 per cent. higher than in 1911 and 40 per cent. higher than in 1910.

The rate of failure of the Bessemer rail was, in 1912, 68 per cent. higher than in 1911 and 56 per cent. higher than in 1910.

The rate of failure of the Bessemer rail was, in 1912, 116 per cent. higher than that of the Open-Hearth; in 1911, 58 per cent. higher than that of the Open-Hearth; in 1910, 94 per cent. higher than that of the Open-Hearth.

(6) A higher percentage of the failed rails are from the upper part of the ingot than from the lower positions.

(7) Particular attention is called to Table No. 3, which shows that for the past four years head failures have predominated except that in 1912 there was a slighty higher percentage of broken rails. It will be remembered that the early part of 1912 was marked by exceptionally severe weather, which was accompanied by an epidemic of broken rails. The Committee feels that this was an abnormal condition, and does not feel that the conclusion implied under (5) of last year's "Deductions" need be modified; namely, that the majority of failures are head failures, such as split or crushed heads, and are due, not to imperfect track conditions, but to defective material in the rail.

CLASSIFIED RAIL FAILURES.

(A) Comparison Between Different Weights of Rail—
Diagram 1—Bessemer Steel.
Diagram 2—Open-Hearth Steel.

(B) Comparison Between Different Sections of Rail—
Diagram 3—Bessemer Steel.
Diagram 4—Open-Hearth Steel.

(C) Comparison Between Different Manufacturers—
Diagram 5—Bessemer Steel.
Diagram 6—Open-Hearth Steel.

(D) Comparison Between Various Weights of Rail—
Diagram 7—Bessemer Steel.
Diagram 8—Open-Hearth Steel.

(E) Failures Per 10,000 Tons New Rail Laid, Classified by Weights, Sections and Railroads—
Diagram 9—Bessemer Steel.
Diagram 10—Open-Hearth Steel.

(F) Failures Per 10,000 Tons New Rail Laid, Classified by Railroads—
Diagram 11—Bessemer Steel.
Diagram 12—Open-Hearth Steel.

(G) Failures Per 10,000 Tons New Rail Laid, Classified by Railroads—
Diagram 13—Bessemer and Open-Hearth Steel.

INFLUENCE ON RAILS OF AMOUNT OF DRAFT IN BLOOMING.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report gives an account of some tests concerning the influence on the finished rail of various rates of reduction in making the bloom from the ingot; or, in other words, the influence of the amount of "draft" in rolling the ingot into a bloom. The work had reference particularly to the transverse ductility of the base and the presence of seams. Five companion ingots of one heat were used and all handled in the same way except that the draft used in making the bloom from the ingot was varied from a heavy reduction per pass in one ingot to a light reduction per pass in the ingot at the other end of the series. The one bloom was made with a few passes and the others were made with successively more passes. The rails were tested by means of drop tests and transverse tests of base. In addition, a sixth companion ingot of the same heat was set aside to cool after soaking, and used to split open to note its condition as regards interior cavities and to make a chemical survey. This work was done at South Bethlehem, Pa., at the works of the Bethlehem Steel Company, who kindly furnished the material and most of the facilities for making the tests. The transverse tests of the base or flange tests, described later, were made at South Bethlehem, Pa., at the Fritz Laboratory of Lehigh University, who kindly furnished the use of their large test-machine and made the tests.

MANUFACTURE.

The steel was basic open-hearth steel, treated with titanium and made by the duplex process; that is, the metal was partly blown in a Bessemer converter and the reduction finished in an open-hearth furnace. Lime, scrap steel and ore were charged to the furnace, melted down, blown Bessemer metal charged and the whole then melted to about .12 or .15 per cent. carbon (by fracture). Molten recarbonizing iron high in manganese and most of the ferro-manganese were added to the furnace. After 2 or 3 minutes the furnace was tapped and ferro-

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silicon, ferro-titanium and the balance of the ferro-manganese were added to the ladle. The mill record of the various materials used are shown in table 1. The steel and rails were made November 8, 1912, heat number D19035.

TABLE I—HEAT CHARGE.

Scrap steel	44,000	lbs.
Ore	3,300	"
Burnt lime	11,800	"
Fluor-spar	500	"
Bessemer metal	92,260	"
Recarbonizer, liquid iron	27,800	"
Ferro-manganese, in furnace	1,000	"
Ferro-manganese, in ladle	200	"
Ferro-silicon	200	"
Ferro-titanium, 15 per cent. alloy	1,030	"
Total charge	169,790	lbs.

The steel was tapped into a large ladle from which it was poured into the molds, which were 19x23 inches at the bottom and tapered about ¼ inch smaller per foot of height. The mill record of the times of operation and amount of steel made were as follows: Furnace tapped at 11:30 a. m., started to pour into molds at 11:55 a. m., ingots stripped 12:00 noon, time into the soaking pits 12:20 p. m. The heat made 22 ingots weighing 148,500 lbs. and 1 butt weighing 3,000 lbs. The butt and ladle scrap were 4,990 lbs. and loss was 13,300 lbs., making a total, as shown in the table, of 169,790 lbs. Six ingots of the heat were used for this investigation, numbers 2 to 7, inclusive, five for rolling into 100-lb. rail of the A. R. A. type A section (see Proceedings American Railway Engineering Association, 1911, Vol. 12, Part 2, p. 143) and the sixth for splitting open. The first of the test ingots was taken out of the soaking pit at 2:45 p. m., and the others were taken out in order at about 15-minute intervals.

The ladle sample, taken while the heat was being poured, gave the following results on analysis: C, .722; P, .021; S, .043; Mn, .71; Si, .104.

INGOT.

One of the ingots, after being in the soaking pit about 3½ hours, was cooled down in a vertical position and afterward split open on the long diameter to note its internal condition as regards size and distribution of cavities, and to use for obtaining drillings with which to make a chemical survey of the ingot. This ingot cold was 64 in. high, 18⅝x 22⅝ in. at the bottom, 17¼x20¾ in. at the top and weighed 6,640 lbs. The ingot was split by sawing with a large composite saw, so that the surface left was an axial plane across the long diameter. This surface,

FIG. 1—LONGITUDINAL AXIAL SECTION OF INGOT AFTER DRILLING.

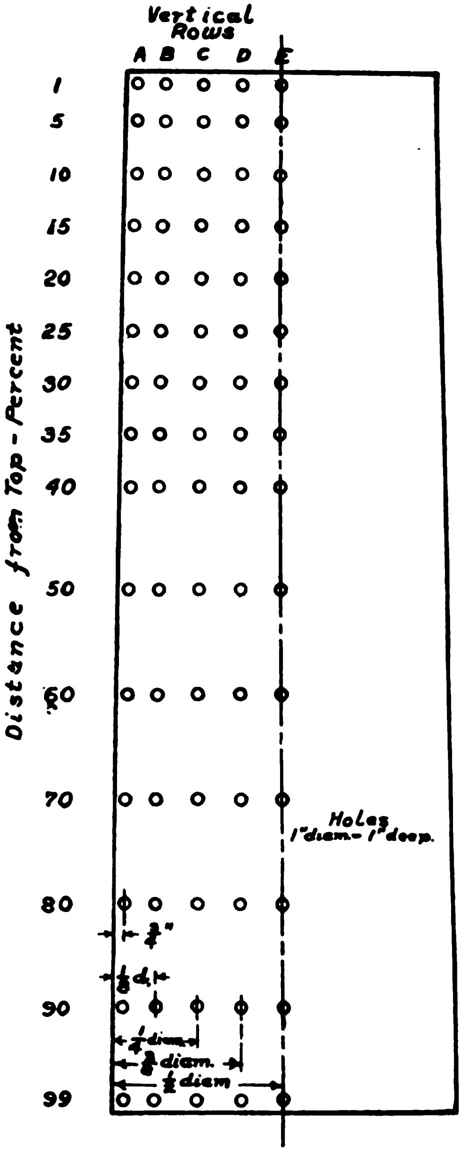

FIG. 2—DRILLING DIAGRAM FOR INGOT.

after drilling for analysis, is shown in Fig. 1. It will be noticed that there was a large tapering cavity or pipe in the upper part of the ingot extending downward from the top to about 40 per cent. of the height, with a bridge across the cavity about 10 per cent. from the top.

ANALYSIS OF INGOT.

A chemical survey was made of the ingot by means of drillings taken as shown in Fig. 2. There were five vertical rows of drillings, 15 samples per row, from one-half of the section, making a total of 75 samples from each ingot, less the number that could not be obtained due to the cavities in the ingot. On each sample determinations were made of carbon (by combustion), phosphorus and sulphur, as shown in tables 2, 3 and 4, and on the samples from the bottom of the ingot determinations of manganese and silicon were made also. For the present investigation it was considered unnecessary to determine the manganese and silicon or all the samples.

TABLE 2—CARBON IN INGOT.

Per cent. from top	A	B	C	D	E
1	.694	....	.680	.668	.640
5	.690	.712	....	.572	....
10	.714	.718	.720	....	.662
15	.696	.706	.724	....	....
20	.712	.694	.788	....	....
25	.722	.712	.770	.772	....
30	.714	.702	.764	.770	....
35	.724	.708	.748	.776	....
40	.710	.696	.774	.708	.682
50	.684	.696	.772	.724	.770
60	.716	.696	.692	.652	.686
70	.700	.696	.684	.668	.630
80	.710	.702	.702	.678	.642
90	.726	.712	.684	.676	.692
99	.714	.724	.748	.722	.714

TABLE 3—PHOSPHORUS IN INGOT.

Per cent. from top	A	B	C	D	E
1	.023	....	.023	.024	.026
5	.023	.023	....	.022	....
10	.021	.023	.024	....	.023
15	.021	.023	.025	....	....
20	.021	.023	.025	....	....
25	.021	.022	.026	.028	....
30	.021	.022	.026	.026	....
35	.021	.022	.026	.026	....
40	.021	.022	.028	.026	.022
50	.021	.023	.028	.025	.025
60	.021	.023	.026	.024	.024
70	.022	.024	.023	.024	.024
80	.022	.024	.023	.023	.023
90	.023	.024	.023	.023	.023
99	.023	.024	.024	.024	.024

TABLE 4—SULPHUR IN INGOT.

Per cent. from top	A	B	C	D	E
1	.038	....	.041	.041	.040
5	.041	.041	....	.038	....
10	.046	.046	.052	....	.037
15	.040	.045	.043	....	....
20	.041	.046	.051	....	....
25	.037	.046	.045	.049	....
30	.043	.046	.045	.040	....
35	.038	.046	.046	.046	....
40	.041	.046	.052	.046	.042
50	.041	.047	.052	.043	.045
60	.040	.045	.041	.040	.038
70	.040	.047	.046	.042	.042
80	.042	.047	.046	.042	.042
90	.043	.045	.043	.041	.042
99	.038	.045	.044	.045	.043

The results of the manganese and silicon determinations are shown in table 5.

TABLE 5—MANGANESE AND SILICON IN INGOT.

Sample.	Mn.	Si.
99A	.73	.112
99B	.73	.112
99C	.73	.110
99D	.73	.102
99E	.73	.100
Average	.73	.107

Probably the samples from the wall of the lower half of the ingot and those along the bottom represent fairly closely the average steel of the ingot and I give in table 6 the average for each element and also the heat analysis. The averages for carbon, phosphorus and sulphur are each the average of the six samples from the wall of the lower half of the ingot and the four samples from the bottom, each average thus being of a total of ten samples. For manganese and silicon the averages are taken from table 5.

TABLE 6—AVERAGE STEEL IN INGOT.

	Ingot.	Ladle Test.
Carbon	.716	.722
Phosphorus	.023	.021
Sulphur	.042	.043
Manganese	.73	.71
Silicon	.107	.104

It will be noticed that the ladle analysis and ingot results show up about the same.

At any given distance from the top of the ingot the extreme variations in composition are in general shown by the axis and the walls of the ingot and to show conveniently the changes from the top to the bottom of the ingot the carbon, phosphorus and sulphur are plotted in Fig. 3. The distance from the top of the ingot in per cent. of the height is shown horizontally and the amounts of the elements are shown vertically. Where samples could not be obtained from the axis because of cavities, the results were taken from row D and this was also done in a few other cases in order to better show the maximum amount of the element in the upper and interior part of the ingot. It will be noticed that the wall showed fairly uniform composition throughout the height

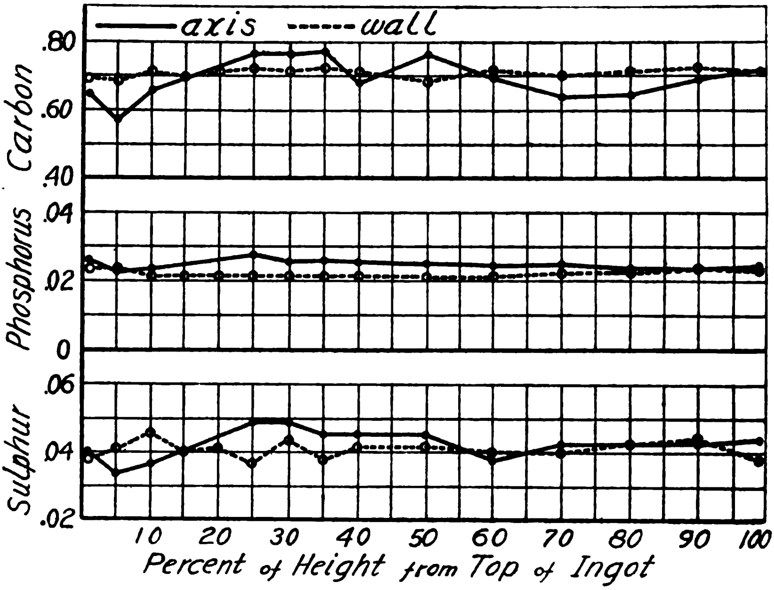

FIG. 3—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF AXIS AND WALL OF INGOT.

of the ingot. The axis showed carbon below the average for about the top 10 per cent. of the height and then in the region between 15 and 50 per cent. from the top there was some increase above the average or segregation. In the lower half of the ingot the axis again showed some lowering of the carbon below the average, or negative segregation. The phosphorus and sulphur showed about the average content along the axis, except for a little increase in the upper part of the ingot, reaching a maximum at about 25 per cent. of the height from the top.

The maximum amounts of positive segregation found at the axis of the ingot and the per cents. of increase above the average content of the ingot are shown in table 7.

TABLE 7—SEGREGATION AT AXIS OF INGOT.

	Maximum Amount.	Increase, per cent.
Carbon	.788	10
Phosphorus	.028	22
Sulphur	.051	21

RAILS.

As explained, ingots 2, 3, 4, 5 and 6 of the heat were rolled into 100-lb. rails of the A. R. A. type A section and the rail-bars were numbered respectively 1, 2, 3, 4 and 5. The ingots were about 19x23 in. at the bottom, about 17½x21½ in. at the top and were all bloomed to about 8x8 in., but with varying amounts of draft per pass. They were bloomed

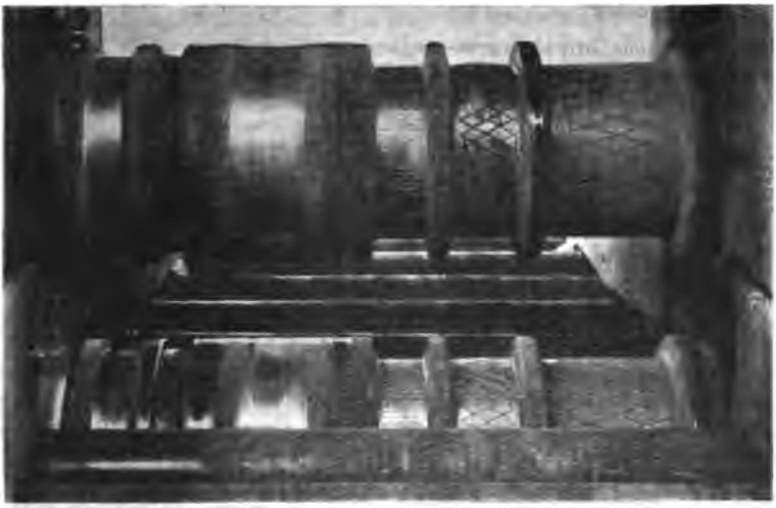

FIG. 4—BLOOMING ROLLS.

by first passing, with the long diameter vertical, through a roll pass 20 in. between collars, with varying amounts of draft until the ingot was reduced to a bloom about 20 in. high. The bloom was turned and reduced to a height of about 10 in. in the same roll pass, making the bloom 20 in. wide and 10 in. high. The bloom was again turned and then run through a pass 10 in. between collars, reduced to a height of 8 in. turned and finally run through a pass 8 in. between collars. In one case (rail-bar number 4) toward the end of the blooming, the bloom was given an extra turn to prevent it from becoming "diagonal." A view of the blooming rolls is given in Fig. 4 intended to show primarily the "ragging," which consisted of diagonal grooves in the 20 and 10 in. passes and transverse grooves in the 8-in. pass. These grooves were 3-16 in. wide and 3-32 in. deep, cut in with a round nose tool.

The number of passes used for each stage of the reduction in blooming is shown in table 8. The rolls were about 27 in. in diameter and their speed averaged about 75 revolutions per minute, turning slower in the first passes and faster in the latter ones.

TABLE 8—NUMBER OF PASSES IN BLOOMING.

	Number of Passes.				
Stage. Size after reduction	Rail-bar 1	Rail-bar 2	Rail-bar 3	Rail-bar 4	Rail-bar 5
A—20 in. wide x 20 in. high.........	1	2	4	6	8
B—20 in. wide x 10 in. high.........	3	5	7	9	12
C—10 in. wide x 8 in. high.........	3	4	6	8	10
D —8 in. wide x 8 in. high.........	1	2	3	4	4
	—	—	—	—	—
Total passes	8	13	20	27	34

These data are shown in another way in table 9, which shows the approximate amount of draft or squeeze per pass in the various stages of reduction in making the bloom from the ingot.

TABLE 9—DRAFT PER PASS IN BLOOMING.

	Inches Draft Per Pass				
Stage. Size after reduction	Rail-bar 1	Rail-bar 2	Rail-bar 3	Rail-bar 4	Rail-bar 5
A—20 in. wide x 20 in. high.........	3.0	1.5	0.8	0.5	0.4
B—20 in. wide x 10 in. high.........	3.3	2.0	1.4	1.1	0.8
C—10 in. wide x 8 in. high.........	4.0	3.0	2.0	1.5	1.2
D— 8 in. high x 8 in. wide.........	2.0	1.0	0.7	0.5	0.5

After being reduced from a height of 23 in. to 20 in., the width is shown as 20 in. instead of the original width of 19 in., because, in being reduced in height, the bloom widens to the distance between the collars on the rolls, which was 20 in.

It will be noticed that the biggest differences in the rate of reduction were made in the early stages of the blooming. In rail-bar 1, the first stage of 3 in. reduction from the ingot was made in one pass, while in rail-bar 5 the same reduction was made in 8 passes, or drafts of 3 in. and 3/8 in., respectively. The second stage was made with drafts of 3.3 in. in rail-bar 1 and 0.8 in. in rail-bar 5, with the other bars ranging in between these.

After blooming, only such croppings were made from the ends of the blooms as were necessary to permit of the bars going through the rolls satisfactorily. Each bloom was cut in two, the first part making three rails, the A, B and C, and the second part making two rails, the D and E. No croppings were made from the rail-bars, but the rough ends were left on the rails, except in the case of rail-bar 1, from which a piece was cut off the top end of the A rail on account of a bad end, and another piece was cut by mistake from between the B and C rails. The blooms were shaped and finished into rails in 11 passes, as shown in Fig. 5.

The weights of the bloom and rail crops and of the rails are shown in table 10.

TABLE 10—WEIGHTS OF CROPPINGS AND RAILS.

	1	2	3	4	5
Bloom crop, top	303	260	248	248	255
Rail crop, top	170	.....	.....	.....	.....
A rail	1,095	1,160	1,270	1,272	1,232
B rail	1,091	1,086	1,088	1,090	1,092
Intermediate piece	104	.....	.....	.....	.....
C rail	1,205	1,340	1,229	1,200	1,225
D rail	1,211	1,255	1,190	1,130	1,255
E rail	1,175	1,221	1,155	1,198	1,190
Bloom crop, bottom	277	357	341	440	337
Total ingot	6,631	6,679	6,521	6,587	6,586

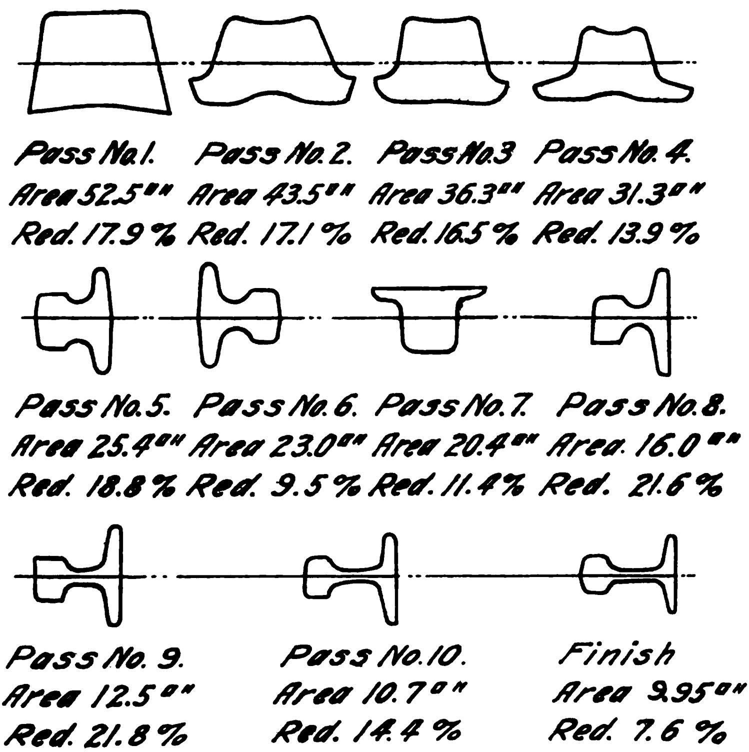

FIG. 5—SHAPING PASSES FROM BLOOM TO FINISHED RAIL.

Samples for analysis as representing the averages of the rail bars were taken from near the top end of each of the D rails by drilling

into the top of the head. The samples were taken from the D 1 pieces used for transverse base tests and the results are shown in table 11, together with the ladle analysis.

TABLE 11—ANALYSES OF RAILS.

Sample	C.	P.	S.	Mn.	Si.
1 D 1	.724	.024	.044	.74	.110
2 D 1	.714	.024	.044	.72	.112
3 D 1	.716	.024	.045	.74	.108
4 D 1	.712	.024	.044	.72	.100
5 D 1	.720	.024	.044	.72	.100
Ladle Test	.722	.021	.043	.71	.104

The entire rail-bar of each of the ingots was used for drop tests and transverse tests of the base or flange tests and was divided into units of one-half rail length each. The pieces cut from each rail and the tests made are shown in table 12.

TABLE 12—TESTS FROM EACH RAIL.

No. 1—2 ft. for transverse base test.
No. 2—4½ ft. for drop test, head in tension.
No. 3—2 ft. for transverse base test.
No. 4—4½ ft. for drop test, base in tension.
No. 5—3½ ft. not used.

No. 6—2 ft. for transverse base test.
No. 7—4½ ft. for drop test, head in tension.
No. 8—2 ft. for transverse base test.
No. 9—4½ ft. for drop test, base in tension.
No. 10—3½ ft. not used.

The distance of each test piece from the top of the ingot, expressed in lbs. and per cent. of weight, is shown in tables 13 to 17, inclusive. This distance is figured to the middle of the test piece.

TABLE 13—TEST PIECES, RAIL-BAR 1, DISTANCE FROM TOP OF INGOT.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
1A1	506	7.6	1B1	1601	24.2	1C1	2796	42.2
2	614	9.2	2	1709	25.8	2	2904	43.8
3	722	10.9	3	1817	27.4	3	3012	45.4
4	830	12.5	4	1925	29.1	4	3120	47.1
6	1056	15.9	6	2151	32.5	6	3346	50.6
7	1164	17.6	7	2259	34.1	7	3454	52.2
8	1272	19.2	8	2367	35.7	8	3562	53.8
9	1380	20.8	9	2475	37.4	9	3670	55.4
1D1	4001	60.4	1E1	5212	78.6			
2	4109	62.0	2	5320	80.2			
3	4217	63.6	3	5428	81.9			
4	4326	65.2	4	5536	83.5			
6	4551	68.8	6	5762	87.0			
7	4659	70.4	7	5870	88.6			
8	4767	72.0	8	5978	90.2			
9	4875	73.5	9	6086	91.8			

TABLE 14—TEST PIECES, RAIL-BAR 2, DISTANCE FROM TOP OF INGOT.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
2A1	293	4.4	2B1	1453	21.8	2C1	2539	38.0
2	401	6.0	2	1561	23.4	2	2647	39.6
3	509	7.6	3	1669	25.0	3	2755	41.3
4	617	9.2	4	1777	26.6	4	2863	42.9
6	843	12.6	6	2003	30.0	6	3089	46.3
7	951	14.2	7	2111	31.6	7	3197	47.9
8	1059	15.9	8	2219	33.2	8	3305	49.5
9	1167	17.5	9	2327	34.8	9	3413	51.1
2D1	3879	58.1	2E1	5134	77.0			
2	3987	59.7	2	5242	78.6			
3	4095	61.3	3	5350	80.2			
4	4203	63.0	4	5458	81.8			
6	4429	66.3	6	5684	85.2			
7	4537	68.0	7	5792	86.8			
8	4645	69.6	8	5900	88.4			
9	4753	71.2	9	6008	90.0			

TABLE 15—TEST PIECES, RAIL-BAR 3, DISTANCE FROM TOP OF INGOT.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
3A1	281	4.3	3B1	1551	23.8	3C1	2639	40.4
2	389	6.0	2	1659	25.4	2	2747	42.1
3	497	7.6	3	1767	27.0	3	2855	43.7
4	605	9.3	4	1875	28.7	4	2963	45.3
6	831	12.7	6	2101	32.2	6	3189	48.8
7	939	14.4	7	2209	33.8	7	3297	50.4
8	1047	16.0	8	2317	35.4	8	3405	52.1
9	1155	17.7	9	2425	37.1	9	3513	53.8
3D1	3868	59.3	3E1	5058	77.5			
2	3976	60.9	2	5166	79.1			
3	4084	62.5	3	5274	80.8			
4	4192	64.1	4	5382	82.4			
6	4418	67.7	6	5608	85.9			
7	4526	69.3	7	5716	87.5			
8	4634	71.0	8	5824	89.2			
9	4742	72.6	9	5932	90.8			

TABLE 16—TEST PIECES, RAIL-BAR 4, DISTANCE FROM TOP OF INGOT.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
4A1	281	4.3	4B1	1553	23.6	4C1	2643	40.2
2	389	5.9	2	1661	25.2	2	2751	41.8
3	497	7.5	3	1769	26.8	3	2859	43.4
4	605	9.2	4	1877	28.5	4	2967	45.1
6	831	12.6	6	2103	32.0	6	3193	48.5
7	939	14.3	7	2211	33.6	7	3301	50.1
8	1047	15.9	8	2319	35.2	8	3409	51.7
9	1155	17.5	9	2427	36.9	9	3517	53.8
4D1	3843	58.4	4E1	4973	75.5			
2	3951	60.0	2	5081	77.1			
3	4059	61.6	3	5189	78.8			
4	4167	63.3	4	5297	80.4			
6	4393	66.7	6	5523	83.9			
7	4501	68.4	7	5631	85.5			
8	4609	70.0	8	5739	87.1			
9	4717	71.6	9	5847	88.7			

TABLE 17—TEST PIECES, RAIL-BAR 5, DISTANCE FROM TOP OF INGOT.

Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.	Test piece	Lbs.	Per cent.
5A1	288	4.4	5B1	1520	23.1	5C1	2612	39.6
2	396	6.0	2	1628	24.7	2	2720	41.3
3	504	7.6	3	1736	26.4	3	2828	43.0
4	612	9.3	4	1844	28.0	4	2986	44.6
6	838	12.7	6	2070	31.4	6	3162	48.0
7	946	14.4	7	2178	33.1	7	3270	49.7
8	1054	16.0	8	2286	34.8	8	3378	51.3
9	1162	17.6	9	2394	36.4	9	3486	53.0
5D1	3837	58.2	5E1	5092	77.3			
2	3945	60.0	2	5200	79.0			
3	4053	61.6	3	5308	80.6			
4	4161	63.2	4	5416	82.4			
6	4387	66.7	6	5642	85.7			
7	4495	68.3	7	5750	87.4			
8	4603	70.0	8	5858	89.0			
9	4711	71.6	9	5966	90.7			

DROP TESTS.

Four drop tests were made of each rail, two with the head in tension and two with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were 3 ft. apart and the anvil was 20,000 lbs., spring supported. The striking surface of the tup and the bearing surfaces of the supports had radii of 5 in. The deflection was measured after the first blow and was taken as the distance between a 3 ft. straight edge and the rail where struck by the tup. Gage marks

TABLE 18—DROP TESTS, RAIL-BAR 1, 3-INCH DRAFT.

No.	Per cent. from top of ingot	Part in tension	Deflection, 1st blow	No. of blows	Elongation, per cent.
1 A 2	9.3	Head	1.22	3	20 L
1 A 7	17.6	"	1.24	2	15 L
1 B 2	25.8	"	1.20	2	10 L
1 B 7	34.1	"	1.23	3	16 L
1 C 2	43.8	"	1.19	3	20 L
1 C 7	52.2	"	1.20	3	22
1 D 2	62.0	"	....	2	10 S
1 D 7	70.4	"	1.27	3	19
1 E 2	80.3	"	....	1	8 S
1 E 7	88.6	"	1.26	2	10 S
Average			1.23	2.4	15.0
1 A 4	12.5	Base	....	1	2 S
1 A 9	20.8	"	1.16	4	12 L
1 B 4	29.1	"	1.17	3	12 L
1 B 9	37.4	"	1.16	3	13
1 C 4	47.1	"	1.15	5	14
1 C 9	55.4	"	....	1	2 S
1 D4	65.2	"	1.12	3	10
1 D9	73.5	"	1.17	4	14
1 E 4	83.5	"	....	1	2 S
1 E 9	91.8	"	....	1	4 S
Average			1.16	2.6	8.5
Gen. Av.			1.19	2.5	11.8

L means interior lamination or pipe. S means seam in base.

1 in. apart were put lengthwise on the side in tension about the middle of the test piece for a distance of 6 in., and the length of the 1-in. space which stretched most at failure was taken as the measure of the ductility of the rail. The results of the drop tests are shown in tables 18 to 22, inclusive.

TABLE 19—DROP TESTS, RAIL-BAR 2, 1.5-INCH DRAFT.

No.	Per cent. from top of ingot	Part in tension	Deflection, 1st blow	No. of blows	Elongation, per cent.
2 A 2	6.0	Head	....	1	4 L
2 A 7	14.2	"	1.21	3	18
2 B 2	23.4	"	1.21	3	15
2 B 7	31.6	"	1.25	3	15
2 C 2	39.6	"	1.21	3	16 S
2 C 7	47.9	"	1.23	3	18
2 D 2	59.7	"	1.29	4	18
2 D 7	68.0	"	1.25	3	20
2 E 2	78.6	"	....	2	9 S
2 E 7	86.8	"	1.22	4	20
Average			1.23	2.9	15.3
2 A 4	9.2	Base	1.13	4	1 2 L
2 A 9	17.5	"	....	1	1 S
2 B 4	26.6	"	1.17	4	12
2 B 9	34.8	"	1.20	3	10
2 C 4	43.9	"	....	1	0 S
2 C 9	51.1	"	1.14	4	12
2 D 4	63.0	"	1.15	3	11
2 D 9	71.2	"	....	1	1 S
2 E 4	81.8	"	1.19	4	11
2 E 9	90.0	"	1.25	4	14
Average			1.18	2.9	8.4
Gen. Av.			1.21	2.9	11.9

L means interior lamination or pipe. S means seam in base.

TABLE 20—DROP TESTS, RAIL-BAR 3, .8-INCH DRAFT.

No.	Per cent. from top of ingot	Part in tension	Deflection, 1st blow	No. of blows	Elongation, per cent.
3 A 2	6.0	Head	1.28	4	16 L S
3 A 7	14.4	"	1.20	3	16
3 B 2	25.4	"	1.23	3	17
3 B 7	33.8	"	1.19	3	19
3 C 2	42.1	"	1.18	3	19
3 C 7	50.4	"	1.20	3	20
3 D 2	60.9	"	1.26	4	20
3 D 7	69.3	"	1.25	3	16
3 E 2	79.1	"	1.24	3	24
3 E 7	87.5	"	1.23	3	20
Average			1.23	3.2	18.7
3 A 4	9.3	Base	1.13	4	13 L
3 A 9	17.7	"	1.17	3	12
3 B 4	28.7	"	1.18	3	15
3 B 9	37.1	"	1.20	4	13
3 C 4	45.3	"	1.18	4	13
3 C 9	53.8	"	1.18	4	14
3 D 4	64.1	"	1.18	4	12
3 D 9	72.6	"	1.22	4	10
3 E 4	82.4	"	1.17	4	12
3 E 9	90.8	"	1.19	4	10
Average			1.18	3.8	12.4
Gen. Av.			1.21	3.5	15.6

L means interior lamination or pipe. S means seam in base.

TABLE 21—DROP TESTS, RAIL-BAR 4, .5-INCH DRAFT.

No.	Per cent. from top of ingot	Part in tension	Deflection, 1st blow	No. of blows	Elongation, per cent.
4 A 2	5.9	Head	1.24	2	14 L
4 A 7	14.3	"	1.26	2	12 L
4 B 2	25.2	"	1.22	2	11
4 B 7	33.6	"	1.22	3	21
4 C 2	41.8	"	1.25	3	15
4 C 7	50.1	"	1.24	3	14
4 D 2	60.0	"	....	2	12
4 D 7	68.4	"	1.23	3	16
4 E 2	77.1	"	1.26	3	18
4 E 7	85.5	"	....	1	9
Average			1.24	2.4	14.2
4 A 4	9.2	Base	1.18	2	10 L
4 A 9	17.5	"	1.14	4	15
4 B 4	28.5	"	1.21	4	11
4 B 9	36.9	"	1.17	3	14
4 C 4	45.1	"	1.11	3	10
4 C 9	53.3	"	....	(1)	(1)
4 D 4	63.3	"	....	(1)	(1)
4 D 9	71.6	"	1.16	4	12
4 E 4	80.4	"	1.21	4	11
4 E 9	88.7	"	1.18	3	12
Average			1.17	3.4	11.9
Gen. Av.			1.21	2.9	13.1

L means interior lamination or pipe. 4C9, 4D2 and 4D4 had scabby bases.

TABLE 22—DROP TESTS, RAIL-BAR 5, .4-INCH DRAFT.

No.	Per cent. from top of ingot	Part in tension	Deflection, 1st blow	No. of blows	Elongation, per cent.
5 A 2	6.0	Head	1.25	3	20
5 A 7	14.4	"	1.22	3	20
5 B 2	24.7	"	1.25	3	20
5 B 7	33.1	"	1.24	4	18
5 C 2	41.3	"	1.23	3	21
5 C 7	49.7	"	1.20	3	18
5 D 2	60.0	"	1.26	3	18
5 D 7	68.3	"	....	2	10
5 E 2	79.0	"	1.27	3	22
5 E 7	87.4	"	1.22	3	23
Average			1.24	3.0	19.0
5 A 4	9.3	Base	1.14	3	10
5 A 9	17.6	"	1.12	4	12
5 B 4	28.0	"	1.18	4	14
5 B 9	36.4	"	....	1	5
5 C 4	44.6	"	1.16	4	14
5 C 9	53.0	"	1.18	4	14
5 D 4	63.2	"	1.18	2	6
5 D 9	71.6	"	1.12	2	5 S
5 E 4	82.4	"	1.20	4	12
5 E 9	90.7	"	1.19	4	14
Average			1.16	3.2	10.6
Gen. Av.			1.20	3.1	14.8

S means seam in base.

The internal defects or "pipes" found in the fractures of the pieces drop-tested are shown in table 23.

TABLE 23—INTERNAL DEFECTS IN RAILS.

Rail-bar.	Test Piece.	Per Cent. from Top of Ingot.	Defect.
1	1A2	9.3	Lamination head to near base.
1	1A7	17.6	¾-in. lamination middle of web.
1	1A9	20.8	1-in. lamination upper part of web.
1	1B2	25.8	1½-in. lamination upper part of web.
1	1B4	29.1	2½-in. lamination middle of web.
1	1B7	34.1	½-in. lamination middle of web.
1	1C2	43.8	1¼-in. lamination middle of web.
2	2A2	6.0	1½-in. lamination upper part of web.
2	2A4	9.2	2-in. lamination upper part of web.
3	3A2	6.0	1-in. lamination lower part of web.
3	3A4	9.3	1-in. lamination middle of web.
4	4A2	5.9	~~Lamination bottom of head to base.~~
4	4A4	9.2	Lamination middle of head to base.
4	4A7	14.3	Lamination bottom of head to near base.
5	....	...	None found.

The seams in the bottom of the base which were found in the drop test are shown in table 24. There may, of course, have been other seams present not opened up by the test, but the ones listed are the ones made noticeable by the test.

TABLE 24—SEAMS IN BASE FOUND IN DROP TEST.

Rail-bar.	Test Piece.	Per Cent. from Top of Ingot.	Depth of Seam. Inch.
1	1A4	12.5	.03
1	1C9	55.4	.04
1	1D2	62.0	.05
1	1E2	80.3	.08
1	1E4	83.5	.03
1	1E7	88.6	.06
1	1E9	91.8	.10
2	2A9	17.5	.02
2	2C2	39.6	.02
2	2C4	43.9	.04
2	2D9	71.2	.10
2	2E2	78.6	.06
3	3A2	6.0	.06
4	....	....	None found
5	5D9	71.6	.02

It will be noticed that a large number of seams in the base showed up in the drop tests of rail-bar 1, made with 3-in. draft, in the early blooming passes. Rail-bar 2, with 1.5-in. draft, also showed a large number of seams, but not as many as rail-bar 1. One seam was opened up in rail-bar 3, none in rail-bar 4 and one in rail-bar 5. The ingots of these bars were bloomed in the early passes with .8, .5 and .4 in. draft, respectively.

DUCTILITY IN DROP TEST.

As already stated the inch which stretched most at failure in the drop test was taken as the measure of ductility of the piece of rail tested.

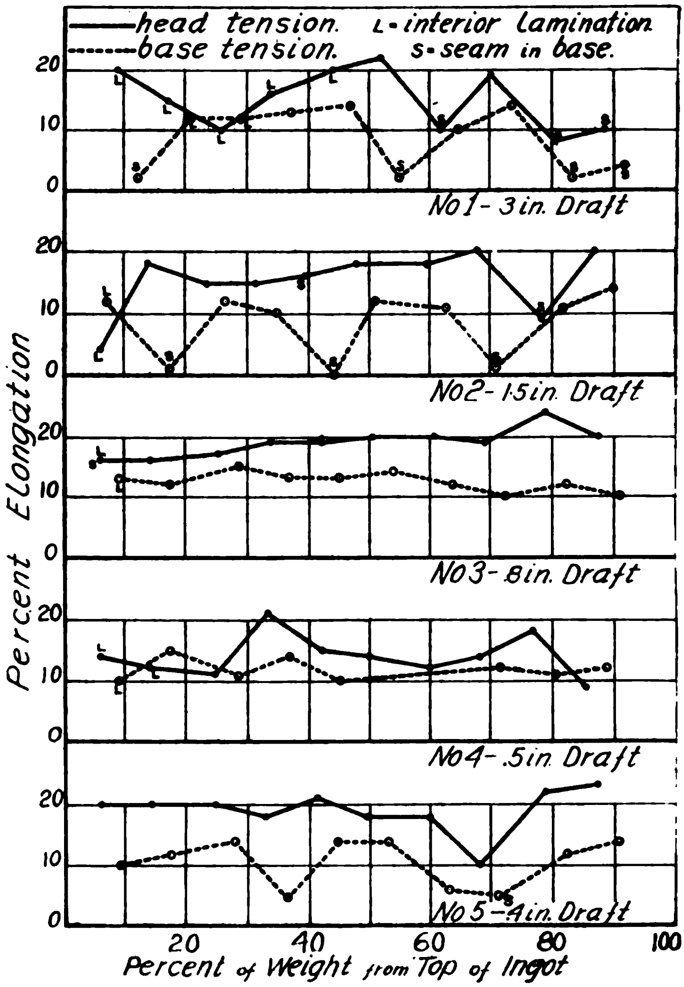

FIG. 6—ELONGATION IN DROP TEST IN RELATION TO DISTANCE FROM TOP OF INGOT.

and the elongation results for the five rail bars are plotted in Fig. 6, the elongation being represented vertically and the distance from the top of the ingot in per cent. of the total weight being represented horizontally. For each rail-bar one curve represents the results with the head in tension and another curve represents the results with the base in tension. The samples which showed laminations or pipes in their fractures are indicated by an L, and those which showed up seams in the bottom of the base after testing are indicated by an S. It will be noticed that the seams were found mostly in rail-bars 1 and 2, and it is also interesting to note that all the pieces that showed up seams were low in ductility with the base in tension and almost all the cases of low ductility showed up seams. With the head in tension also, the presence of a seam in the base lowered the ductility somewhat in most cases.

Fig. 7 is given as an interesting exhibit to show how a seam in the base may be the initial point of a premature failure in the drop test.

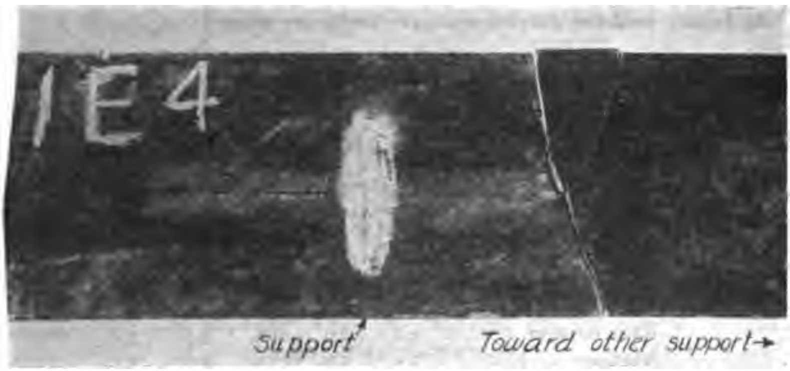

FIG. 7—SAMPLE OF RAIL TESTED WITH THE BASE IN TENSION IN THE DROP TEST, SHOWING HOW A SEAM IN THE BASE WAS THE ORIGIN OF THE FAILURE.

This is a view of the base of about 16 in. of test piece 1E4 of rail-bar 1, showing a short distance either side of one of the supports, this piece having been tested with the base in tension, that is, with the base on the two supports, with a span of 3 ft. The piece broke on the first blow from 20 ft. and the maximum stretch of the base under the place where the tup struck the head was 2 per cent., but the fracture occurred about 5 in. from one of the supports. The support had a radius of 5 in. and the bearing surface was straight transversely. The indentation made by the support into the base is indicated more strongly by white chalk, showing that the impression was greatest at the center and that the edges of the flanges had "curled up" from the support when the load came on. It will be noticed that the seam opened up, due undoubtedly to the com-

pression spreading the metal sideways. The seam opened up both sides of the support and after running along for about 5 in. toward the other support, the crack started out to the edge of the flange, resulting in a fracture of the whole section. *It will thus be seen that, although the rail was tested primarily longitudinally as a beam, the transverse strains at the support opened up a seam, followed by a failure long before the longitudinal ductility was exhausted.* In other words, this failure may be said to be due to low transverse ductility in the bottom of the base.

INFLUENCE OF DRAFT IN BLOOMING ON DROP TEST RESULTS.

The average results in the drop tests of the several rail-bars are collected together in table 25, showing the deflection after the first blow from 20 ft., the number of the blows that it took to break the rail, and the elongation after breaking. The average head tension, the average base tension and the general average results are given.

TABLE 25—AVERAGE RESULTS IN DROP TEST.

Rail-bar number	1	2	3	4	5
Initial draft, ins.	3.0	1.5	.8	.5	.4
Deflection, first blow—					
Head tension	1.23	1.23	1.23	1.24	1.24
Base tension	1.16	1.18	1.18	1.17	1.16
Average	1.19	1.21	1.21	1.21	1.20
Number of blows, 20 ft.—					
Head tension	2.4	2.9	3.2	2.4	3.0
Base tension	2.6	2.9	3.8	3.4	3.2
Average	2.5	2.9	3.5	2.9	3.1
Elongation—					
Head tension	15.0	15.3	18.7	14.2	19.0
Base tension	8.5	8.4	12.4	11.9	10.6
Average	11.8	11.9	15.6	13.1	14.8

The general average deflection and the general average number of blows are plotted in Fig. 8 in relation to the initial draft in blooming. On this figure are also plotted the elongation with the head in tension, the base in tension and the general average elongation. Although this does not show a regularity of relationship between the initial draft in blooming and the results in the drop test, it indicates that the average number of blows was somewhat less with the large drafts than with the smaller ones. The ductility also was somewhat less with the large drafts. A study of the individual results as plotted in Fig. 6 indicates that the lower averages are due to the low results where seams showed up, mostly with initial drafts of 1.5 and 3 in.

TRANSVERSE TESTS OF BASE.

Transverse tests of the base were made of four pieces from each rail, each piece being two feet long. The method of making the test was to support the piece of rail on two supports placed oposite each

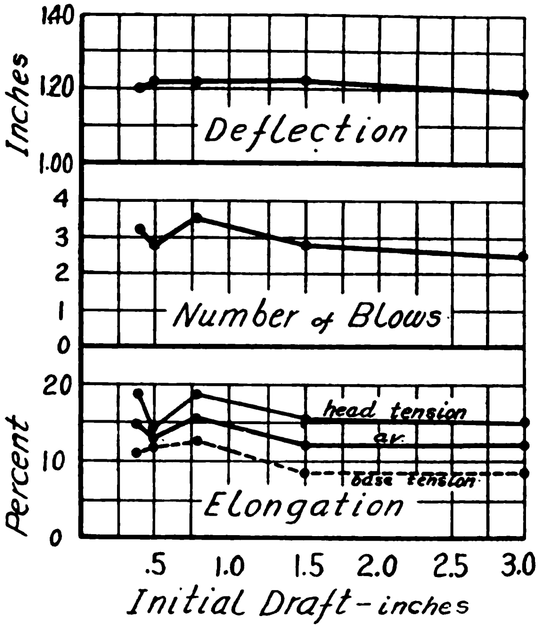

Fig. 8—Results of Drop Test in Relation to Amount of Initial Draft in Blooming.

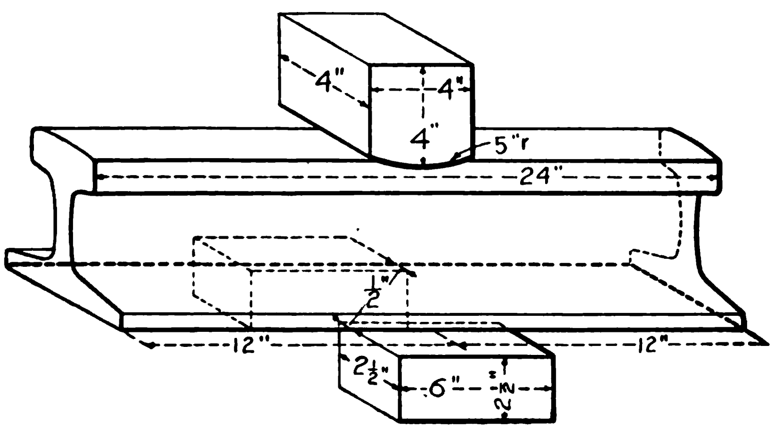

Fig. 9—Method of Making Transverse Test of Base.

other near the edges of the flanges under the middle of its length. The supports were 6 in. long and placed one-half inch in from the sides of flanges, and the load was applied in the test-machine to the head of rail at the middle. The general arrangement is shown in Fig. 9. These tests were made in the 800,000-lb. test-machine of Lehigh University at South Bethlehem, Pa., and Fig. 10 is given showing a piece of rail in place in the machine ready for test. The load was measured that it took to break the rail. The transverse elongation was measured by putting a prick-punch mark on the center line of the base and then marking two one-inch spaces on each side of this crosswise on the bottom of the base and at the middle of the length of the piece tested. The greatest extension

FIG. 10—PIECE OF RAIL IN TEST-MACHINE READY FOR TRANSVERSE TEST OF BASE.

after breaking in any one of the four spaces was taken as the measure of transverse ductility. The sag of the unbroken flange was measured and was taken as the distance from a straight edge laid on the bottom of the base near the edge of the unbroken flange to the flange where bent most from the straight surface of the base. Some of the pieces showed dark seams in the bottom of base and their depths were measured.

A few samples of the various types of fracture are shown in Fig. 11, from which it will be noted that in some cases a short curved piece broke out of the flange, while in other cases a long piece was broken out

with a long, straight break at or near the middle of the flange. A sample of the seams found in some of the pieces is shown in Fig. 12.

The results of the transverse tests of the base are shown in tables 26 to 30, inclusive.

FIG. 11—SAMPLES OF RAIL AFTER MAKING TRANSVERSE TEST OF BASE.

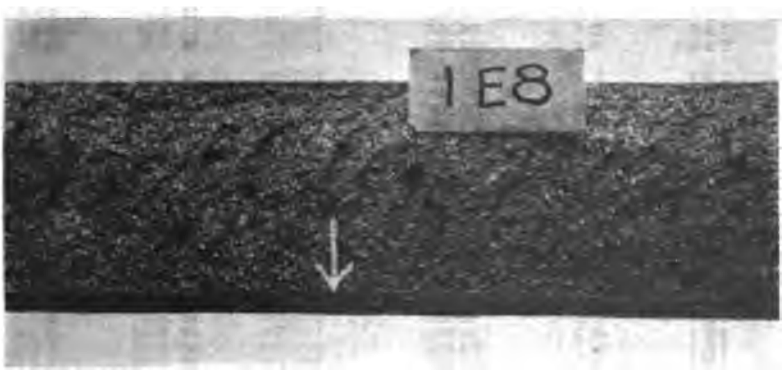

FIG. 12—VERTICAL LONGITUDINAL FRACTURE OF FLANGE, SHOWING LONGITUDINAL SEAM IN BOTTOM OF BASE.

TABLE 26—TRANSVERSE TESTS OF BASE, RAIL-BAR 1, 3-INCH DRAFT.

No.	Per cent. from top of ingot	Load, pounds	Transverse elongation, per cent.	Sag, inches	Depth of seam, inches
1 A 1	7.6	261,900	2	.16	..
1 A 3	10.9	217,000	0	.06	.05
1 A 6	15.9	238,800	1	.14	..
1 A 8	19.2	218,400	0	.06	.03
1 B 1	24.2	233,500	1	.10	..
1 B 3	27.4	250,300	2	.16	..
1 B 6	32.5	273,400	3	.18	..
1 B 8	35.7	213,150	0	.06	slight
1 C 1	42.2	268,700	2	.14	..
1 C 3	45.4	168,400	1	.03	.04
1 C 6	50.6	246,500	2	..	..
1 C 8	53.8	246,050	1	.01	.05
1 D 1	60.4	237,250	2	.08	.20 oblique
1 D 3	63.6	122,300	0	.02	.06
1 D 6	68.8	255,000	1	.19	..
1 D 8	72.0	246,300	1	.10	..
1 E 1	76.8	201,000	1	.06	..
1 E 3	81.9	93,700	0	.03	.12
1 E 6	87.0	268,000	2	.17	..
1 E 8	90.2	137,500	0	.01	.09
Average		220,303	1.1	.098	

TABLE 27—TRANSVERSE TESTS OF BASE, RAIL-BAR 2, 1.5-INCH DRAFT.

No.	Per cent. from top of ingot	Load, pounds	Transverse elongation, per cent.	Sag, inches	Depth of seam, inches
2 A 1	4.4	225,650	1	..	.07
2 A 3	7.6	258,550	2	.12	..
2 A 6	12.6	196,350	1	..	slight
2 A 8	15.9	201,000	1	.06	.04
2 B 1	21.8	158,800	1	.01	slight
2 B 3	25.0	260,350	2	.16	..
2 B 6	30.0	210,100	1	.04	..
2 B 8	33.2	271,500	2	.16	..
2 C 1	38.0	243,100	1	.09	..
2 C 3	41.3	196,550	1	..	.04
2 C 6	46.3	275,960	2	.20	..
2 C 8	49.5	248,650	1	.07	..
2 D 1	58.1	253,150	0	.02	.03
2 D 3	61.3	196,600	0	.04	..
2 D 6	66.3	247,650	2	.12	..
2 D 8	69.6	230,300	1	.10	.03
2 E 1	77.0	86,000	0	.01	.06
2 E 3	80.2	141,350	1	.02	.06
2 E 6	85.2	218,300	1	.05	..
2 E 8	88.4	220,300	1	.07	..
Average		217,110	1.1	.079	

TABLE 28—TRANSVERSE TESTS OF BASE, RAIL-BAR 3, .8-INCH DRAFT.

No.	Per cent. from top of ingot	Load, pounds	Transverse elongation, per cent.	Sag, inches	Depth of seam, inches
3 A 1	4.3	251,000	2	.12	..
3 A 3	7.6	256,200	2	.12	..
3 A 6	12.7	204,000	1	.08	..
3 A 8	16.0	233,150	1	.08	..
3 B 1	23.8	188,700	0	.04	..
3 B 3	27.0	266,800	1	.18	..
3 B 6	32.2	256,700	1	.12	..
3 B 8	36.4	274,950	3	.16	..
3 C 1	40.4	276,400	2	.16	..
3 C 3	43.7	270,000	2	.18	..
3 C 6	48.8	279,750	1	.15	..
3 C 8	52.1	251,950	2	..	..
3 D 1	59.3	203,000	1	.06	..
3 D 3	63.5	241,600	2	.12	..
3 D 6	67.7	268,000	2	.14	..
3 D 8	71.0	264,250	2	.14	..
3 E 1	77.5	274,500	2	.16	..
3 E 3	80.8	266,500	1	.14	..
3 E 6	86.9	275,600	2	.16	..
3 E 8	89.2	275,800	2	.19	..
Average		253,443	1.6	.132	

TABLE 29—TRANSVERSE TESTS OF BASE, RAIL-BAR 4, .5-INCH DRAFT.

No.	Per cent. from top of ingot	Load, pounds	Transverse elongation, per cent.	Sag, inches	Depth of seam, inches
4 A 1	4.3	256,000	2	.15	..
4 A 3	7.5	261,000	3	.14	..
4 A 6	12.6	262,050	2	.17	..
4 A 8	15.9	172,500	1	.08	slight
4 B 1	23.6	266,750	1	.04	.02
4 B 3	28.8	255,800	2	.14	..
4 B 6	32.0	268,200	2	.16	..
4 B 8	35.2	268,000	2	.18	..
4 C 1	40.2	266,850	2	.23	..
4 C 3	43.4	261,550	1	.14	..
4 C 6	48.5	239,050	1	.10	..
4 C 8	51.7	276,400	2	.16	..
4 D 1	58.4	(218,600)	(0)	(.05)*	..
4 D 3	61.6	(100,000)	(0)	(.02)*	..
4 D 6	66.7	143,600	1	.01	..
4 D 8	70.0	252,100	1	.12	..
4 E 1	75.5	272,350	2	.15	..
4 E 3	78.8	267,100	2	.14	..
4 E 6	83.9	279,600	2	.14	..
4 E 8	87.1	274,100	0	.08	..
Average		246,611	1.6	.128	

*Base scabby in samples 4D1 and 4D3. These results not included in average.

TABLE 30—TRANSVERSE TESTS OF BASE, RAIL-BAR 5, .4-INCH DRAFT.

No.	Per cent. from top of ingot	Load, pounds	Transverse elongation, per cent.	Sag, inches	Depth of seam inches
5 A 1	4.4	247,400	1	..	.03
5 A 3	7.6	250,550	2	..	..
5 A 6	12.7	256,100	2	.14	..
5 A 8	16.0	233,000	2	.06	..
5 B 1	23.1	264,900	1	.14	..
5 B 3	26.4	249,450	2	.14	..
5 B 6	31.4	272,450	3	.17	..
5 B 8	34.8	260,950	2	.15	..
5 C 1	39.6	247,300	1	.12	..
5 C 3	43.0	236,000	1	..	..
5 C 6	48.0	261,250	2	.13	..
5 C 8	51.3	274,800	1	.15	..
5 D 1	58.2	266,400	2	.14	..
5 D 3	61.6	266,300	2	.17	..
5 D 6	66.7	217,750	1	.07	slight
5 D 8	70.0	240,800	2	.10	..
5 E 1	77.3	260,950	2	.16	..
5 E 3	80.6	267,100	2	.18	..
5 E 6	85.7	274,750	3	.17	..
5 E 8	89.0	245,900	2	.14	..
Average		254,705	1.8	.137	

The results showing the breaking load are plotted in Fig. 13 for each of the five rail-bars, the distance from the top of the ingot in per cent. of the weight being shown horizontally and the breaking load, in pounds, vertically. Each piece in which a seam was found in the bottom of the base is indicated by an "s." The most noticeable feature is perhaps the large number of seams found in rail-bars 1 and 2, with 3 in. and 1.5 in., respectively, of initial draft. Rail-bar 3 with .8-in. draft showed no seams. Rail-bar 4 with .5-in. and rail-bar 5 with .4-in. draft each showed two small seams. It will be noticed that the presence of a seam was attended very largely with a low breaking load. The transverse strength of the base was rather uneven along the bar, especially in bars 1 and 2, although bar 5 showed some approach toward uniformity along the bar. This irregularity appears to have been due mostly to seams and partly, perhaps, to a condition that may be called "grain" in a longitudinal direction. The seams had dark sides, evidently caused by the action of the air on an open crack in hot metal, but occasionally portions of a seam were found that were not discolored; in other words, there was a cleavage line that had not been exposed to the action of the air.

Fig. 14 is given showing the sag of the unbroken flange along each of the rail-bars in relation to the distance from the top of the ingot. In a general way, the same remarks apply to those curves that were made concerning the curves showing the breaking load.

Fig. 15 is given showing the breaking load and the sag of flange plotted in relation to the depth of the seam. Rail-bar 3 showed no seams,

and the average breaking load and average sag of flange of this bar were taken for plotting on the diagrams to represent metal without seams. *It will be noted that a seam decreased the transverse strength of the base and also decreased the sag of flange still more rapidly. With*

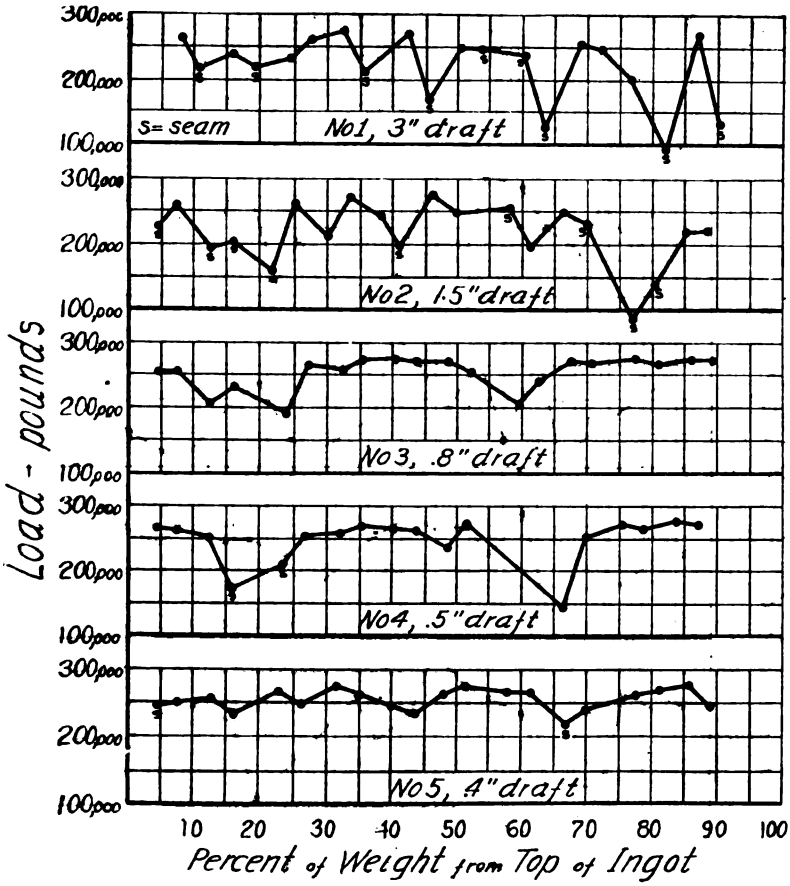

FIG. 13—BREAKING LOAD IN TRANSVERSE TEST OF BASE IN RELATION TO DISTANCE FROM TOP OF INGOT.

a seam of .06, or 1-16 inch deep, the decrease in strength amounted to about 25 per cent and the decrease of sag of flange amounted to about 75 per cent.

The average results of the several rail-bars are collected together in table 31, showing the breaking load, the transverse elongation and the sag of the unbroken flange.

TABLE 31—AVERAGE RESULTS OF TRANSVERSE TESTS OF BASE.

Rail-bar	Initial Draft, inches.	Load, lbs.	Transverse Elongation, per cent.	Sag of Flange, inches.
1	3.0	220,303	1.1	.093
2	1.5	217,110	1.1	.079
3	0.8	253,443	1.6	.132
4	0.5	248,611	1.6	.123
5	0.4	254,705	1.8	.137

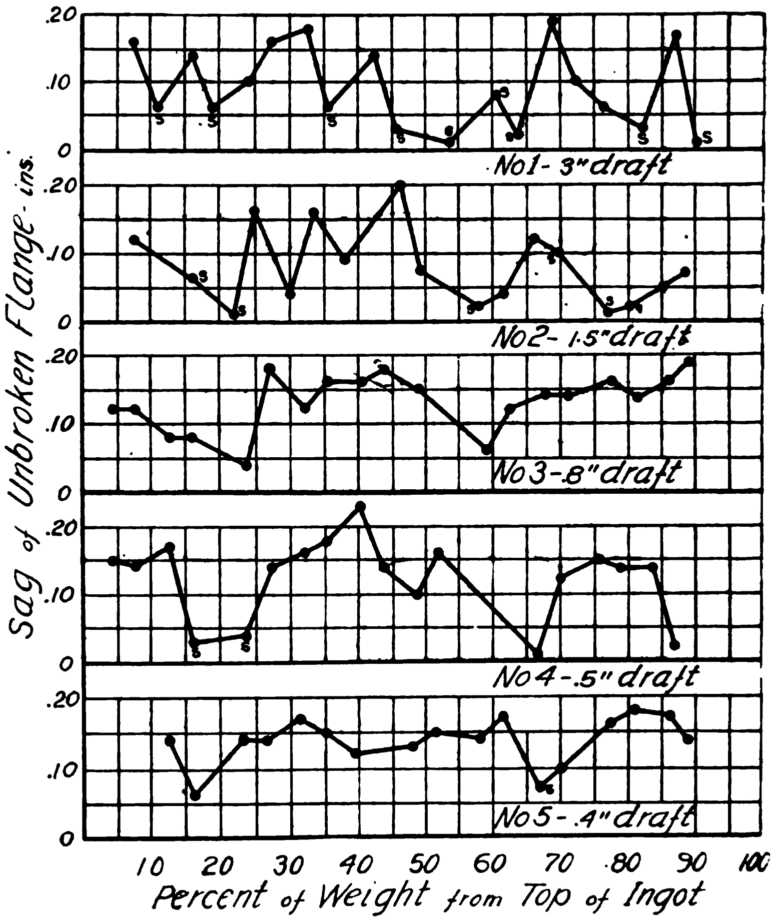

FIG. 14—SAG OF FLANGE IN TRANSVERSE TEST OF BASE IN RELATION TO DISTANCE FROM TOP OF INGOT.

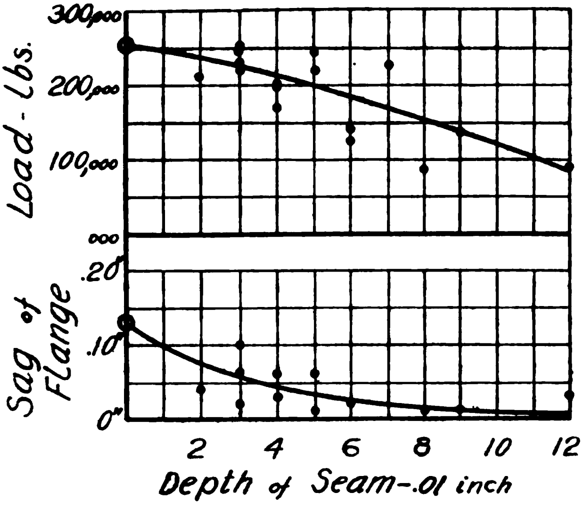

FIG. 15—BREAKING LOAD AND SAG OF FLANGE AS RELATED TO DEPTH OF SEAM IN BOTTOM OF BASE.

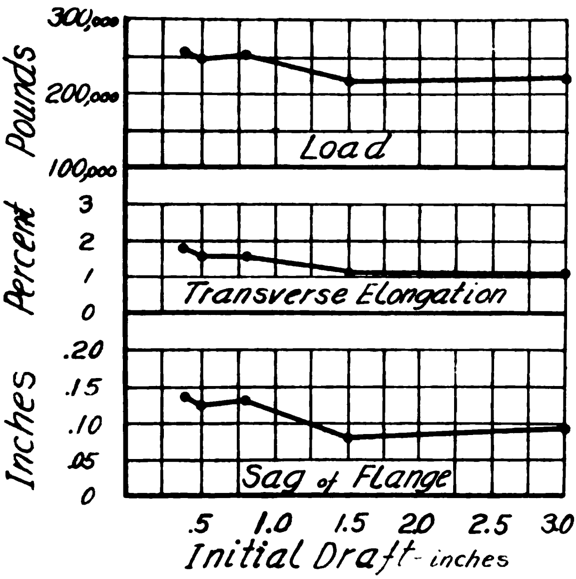

FIG. 16—RESULTS OF TRANVERSE TEST OF BASE AS RELATED TO AMOUNT OF INITIAL DRAFT IN BLOOMING.

These results are plotted in Fig. 16 in relation to the amount of initial draft in blooming. It will be noticed that *the average results of the bars made with 3-in. and 1.5-in. initial draft in blooming were lower than of the bars made with .8-in. or less draft, and this, as already explained appears to be due mostly to the large number of seams found in the bars made with heavy draft.*

SUMMARY.

1. An investigation was made concerning the influence on the finished rail of the amount of draft in rolling the ingot into a bloom, and particularly with reference to the transverse ductility of the base and the presence of seams. Five companion ingots of one heat of titanium treated open-hearth steel were used and all handled in the same way, except that the draft used in making the bloom from the ingot was varied from about 3 in. per pass in the initial passes down to about .4 in. per pass in the early passes as the smallest rate of reduction used. These ingots were rolled into rails and in addition another companion ingot of the same heat was cooled and split open to note its interior condition as regards cavities and to make a chemical survey.

2. This work was done at South Bethlehem, Pa., at the works of the Bethlehem Steel Co. who kindly furnished the material and most of the facilities for making the tests. The transverse tests of the base mentioned later were made at South Bethlehem, Pa., at the Fritz Laboratory of Lehigh University, who kindly furnished the use of their 800,000-lb. test machine and made the tests.

3. The ingot split open had a large tapering cavity or pipe in the upper part of the ingot extending downward from the top to about 40 per cent. of the height, with a bridge across the cavity about 10 per cent. from the top.

4. A chemical survey was made of this ingot by means of 15 samples from each of five vertical rows from one-half of the section face, making a total of 75 samples from the ingot, minus the samples which could not be taken on account of cavities. On each sample determinations were made of carbon, phosphorus and sulphur and on some of them of manganese and silicon also.

5. There was a little segregation of carbon, phosphorus and sulphur around the pipe and a little negative segregation of carbon in the interior and lower part of the ingot.

6. The rails were 100 lbs., of the A. R. A. type A section and were cut up for drop tests (some with the head and some with the base in tension) and transverse tests of the base.

7. The rail-bars made with 3-in. and 1.5-in. initial drafts in blooming showed up a considerable number of seams in the bottom of the base in both the drop tests and the transverse tests of the base. The other bars made with .8, .5 and .4-in., respectively of initial draft, each showed a few small seams.

8. An example is given of a piece of rail with a seam in the base that was tested in the drop machine in the usual manner as a girder, with the base in tension, and in which the longitudinal seam appeared to be the point of origin of a failure before the longitudinal ductility was exhausted. In brief, the explanation seems to be that the spread of the metal at one of the supports opened up a seam, which crack then resulted in a failure through the whole section, several inches from the support.

9. In the drop test the bars made with light initial draft in blooming stood somewhat more blows and showed some greater ductility than those made with heavy draft and this appeared to be due to the large number of seams in the bars made with heavy draft.

10. Transverse tests of the base were made by supporting pieces of rail 2 ft. long, on two supports placed opposite each other near the edges of the flanges under the middle of the length of the piece tested. The supports were 6 in. long and were placed ½ in. in from the sides of the flanges. The load was applied in the test machine to the head of the rail at the middle.

11. The average load required to break a rail thus tested and the average transverse ductility was greater with the bars made with light draft than with the bars made with heavy draft. This appeared to be due again to the large number of seams found in the bars with heavy draft.

12. To sum up it may be said that rails made with initial drafts in blooming of 3 in. and 1.5 in. contained a larger number and deeper seams in the base than those made with .8 in. or less of initial draft. This resulted in poorer results in the drop tests and transverse tests of the base in the rails made with the heavier drafts. These results should be considered only as indicative and final conclusions should be withheld until sufficient work along this line has been done to warrant them.

COMPARISON OF BASIC AND ACID OPEN-HEARTH RAILS, AND INFLUENCE OF REHEATING COLD BLOOMS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation concerning rails made of acid open-hearth steel compared with those made of basic open-hearth steel and concerning the influence on rails of reheating blooms that had been allowed to become cold. Two ingots were taken from a regular rail heat of basic open-hearth steel, one ingot bloomed and the hot bloom put through a reheating furnace or given a "wash" heat and then rolled into 100-lb. rails. The other ingot was bloomed, the bloom allowed to become cold, reheated the next day and then rolled into rails of the same section. Two similar ingots were taken from a heat of acid open-hearth steel and handled in the same manner as the two basic ingots. The rails were then cut up for drop tests and transverse tests of the base, the purpose of the work being primarily to compare the transverse properties of the base. The work was done mostly at Steelton, Pa., at the works of the Pennsylvania Steel Co., who kindly furnished the material and most of the facilities for the investigation. The transverse tests of the base were made at Baltimore, Md., at the laboratory of the Baltimore & Ohio R. R., who kindly made the tests, as the test machines at Steelton were not of sufficient capacity for this work.

MANUFACTURE.

The acid and basic open-hearth processes are in a general way similar, with the essential difference that in the basic process a large amount of lime is used in the operation of melting down, which lime removes some of the phosphorus contained in the furnace charge, whereas no lime is used in the acid charge. This difference in process calls for a difference in the material in the hearth of the furnace; in the acid hearth fire brick of usual composition is used, whereas in the basic process the hearth must be of magnesia or basic material. The ordinary fire brick high in silica would be attacked by the lime charged in the basic process. In

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the acid process no phosphorus is removed, and the material charged to the furnace must be low in phosphorus or the steel will be high in this element, whereas in the basic process the raw material may be high in phosphorus and the resulting steel low in phosphorus.

The basic steel used was heat 22,217, made January 8, 1913. Lump limestone was charged to the furnace, then scrap steel, then liquid blast furnace iron and the whole worked down with ore to about .20 per cent. carbon (by fracture) and the phosphorus determined by a quick method. The metal was tapped into the pouring ladle, liquid recarbonizing iron being added at the same time, together with some cold 80 per cent. ferro-manganese and 50 per cent. ferro-silicon.

The acid steel used was heat 14,061, made January 10, 1913. Scrap steel and cold pig iron were charged into the furnace and worked down with ore to the required carbon. The metal was tapped into the pouring ladle, adding cold 80 per cent. ferro-manganese, 50 per cent. ferro-silicon and a small amount of coke also into the ladle.

The mill record of the amounts of material used in these two heats is shown in table 1. The amount of the coke used in the acid heat was not recorded.

TABLE 1—HEAT CHARGES.

	Basic Heat 22,217.	Acid Heat 14,061.
Liquid blast furnace iron	85,000 lbs.	......
Cold blast furnace iron	......	31,000 lbs.
Scrap steel	90.000 lbs.	89,000 lbs.
Ore	4,000 lbs.	2,000 lbs.
Limestone	20,700 lbs.	......
Recarbonizer, liquid iron	29,000 lbs.	......
Ferro-manganese, 80 per cent	1,500 lbs.	1,000 lbs.
Ferro-silicon, 50 per cent	100 lbs.	150 lbs.

The steel was poured into open-top iron molds, 18½x18½ in. at the bottom and tapered one inch in six feet. After stripping, the ingots were placed into soaking pits and afterward rolled into blooms, 7¾x9⅛ in. Only small discards were made from the ends of the blooms. After blooming, each bloom was cut into three parts, part 1 making the A rail, part 2 making the B and C rails and part 3 making the D and E rails. The three parts of one bloom from each heat were at once placed hot into a reheating furnace, given a "wash" heat and then rolled into rails. The three parts of the other bloom of each heat were allowed to become cold, placed into the reheating furnace the next day and afterward rolled into rails. The times of these various operations are shown in table 2.

TABLE 2—TIMES OF OPERATIONS.

	Basic Heat 22,217.		Acid Heat 14,061.	
Rail-bar number	1	2	3	4
Date	Jan. 8	Jan. 8	Jan. 10	Jan. 10
Time into soaking pit	12:20 p. m.	12:20 p. m.	2:35 p. m.	2:35 p. m.
Time bloomed	2:39 p. m.	2:30 p. m.	4:27 p. m.	4:23 p. m.
Date into reheating furnace	Jan. 8	Jan. 9	Jan. 10	Jan. 11
Time into reheating furnace	2:41 p. m.	2:30 p. m.	4:30 p. m.	9:40 a. m.
Time out of reheating furnace	3:18 p. m.	4:25 p. m.	4:54 p. m.	11:55 a. m.

Samples for analysis were taken from the head of the top end of the D rail of each of the rail-bars, and the results of these analyses, together with the analyses of the ladle samples, are shown in table 3.

TABLE 3—ANALYSES.

	Basic Heat 22,217.			Acid Heat 14,061.		
	Ladle.	1 D 1.	2 D 1.	Ladle.	3 D 1.	3 D 4.
Carbon	.67	.73	.73	.64	.64	.63
Phosphorus	.019	.015	.018	.032	.035	.030
Sulphur	.052	.064	.069	.047	.056	.054
Manganese	.73	.75	.75	.70	.71	.71
Silicon	.15	.15	.17	.14	.10	.10
Copper	...	.14	.16	...	.16	.18
Nickel	.53	.52	.48	.54	.42	.42
Chromium	.30	.30	.30	.17	.15	.07

It will be noticed that in most cases the ladle sample and the corresponding samples from the rails gave about the same results. In basic heat 22,217, however, the carbon showed low in the ladle sample as compared with the results from the rails, the ladle sample showing .67 per cent. carbon and the rails showing .73 per cent. carbon. It was desired to have about the same carbon in the two heats, but, according to the above results. the basic rails contained .09 per cent. more carbon than the acid rails.

RAILS.

The several ingots were rolled into 100-lb. rails of the A. R. R. type A section* (see Proceedings American Railway Engineering Association, 1911, Vol. 12, part 2, page 143). The ingots, 18½x18½ in., were bloomed in a three-high mill to 7¾x9⅛ in. in eight passes and formed into rails in 11 passes, making a total of 19 passes from the ingot to the rail. The dimensions and other information concerning the blooming passes are shown in Table 4.

TABLE 4—BLOOMING PASSES.

Pass Number	Size In.	Radius on Corner In.	Area Sq. In.	Reduction Per Cent.
Ingot	18½x18½	2	338.8	
1	16⅛x18⅜	2½	290.9	14.1
2	14⅛x18⅜	2½	254.2	12.6
3	15⅝x14	2¼	214.4	15.7
4	13¼x14	2¼	181.2	15.5
5	11⅛x13⅛	1¾	143.4	20.8
6	8⅞x13⅛	1¾	113.9	20.6
7	10⅛x 9⅛	1	91.5	19.6
8	7¾x 9⅛	1	69.9	23.7

The areas and reductions in each of the shaping passes are shown in Table 5.

TABLE 5—SHAPING PASSES.

Number	Area Sq. In.	Reduction Per Cent.	Number	Area Sq. In.	Reduction Per Cent.
1	60.66	13.17	7	22.88	17.75
2	50.94	16.02	8	18.48	19.23
3	43.55	14.50	9	13.74	25.65
4	37.20	14.58	10	10.94	20.38
5	32.90	11.58	11	9.95	9.05
6	27.82	15.44			

The first six shaping passes, which may be called roughing passes, are shown in Fig 1, and the last five shaping passes, which may be called finishing passes, are shown in Fig. 2.

The rail-bar from the basic ingot, the bloom of which was not allowed to get cold, was called No. 1; that from the basic ingot, the bloom of which was allowed to get cold, was called No. 2; the corresponding acid rail-bars were called Nos. 3 and 4, respectively. The weights, in pounds, of the bloom crops and the rails are shown in Table 6.

TABLE 6—WEIGHTS OF CROPPINGS AND RAILS.

	1	2	3	4
Bloom crop, top..........	135	162	89	86
A rail	1,204	1,194	1,064	1,090
B rail	1,144	952	1,154	1,192
C rail	960	1,168	1,147	1,052
D rail	1,140	1,142	980	1,070
E rail	920	918	838	1,044*
Bloom crop, bottom......	120	115	120	193
Total ingot	5,623	5,651	5,392	5,727

The entire rail-bar of each of the ingots was used for drop tests and transverse tests of the base, and was divided into units of one-half rail

length each. The pieces cut from each rail and the tests made are shown in Table 7. The No. 10 piece was sometimes longer and sometimes shorter than shown in the table, as the rails varied in length.

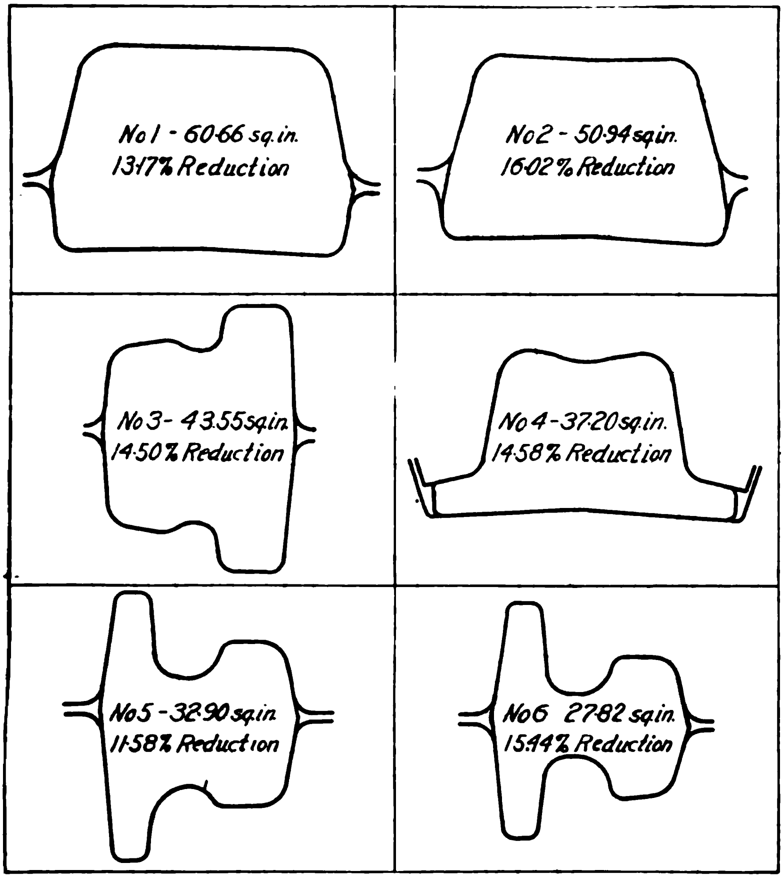

FIG. 1—ROUGHING PASSES.

TABLE 7—TESTS FROM EACH RAIL.

No. 1. 2 ft. for transverse test of base.
No. 2. 4½ ft. for drop test, with head in tension.
No. 3. 2 ft. for transverse test of base.
No. 4. 4½ ft. for drop test, with base in tension.
No. 5. 3½ ft. not used.

No. 6. 2 ft. for transverse test of base.
No. 7. 4½ ft. for drop test, with head in tension.
No. 8. 2 ft. for transverse test of base.
No. 9. 4½ ft. for drop test, with base in tension.
No. 10. 3½ ft. not used.

The distance of each test piece from the top of the ingot, expressed in pounds and in per cent of weight, is shown in Tables 8 to 11, inclusive. This distance is figured to the middle of the test piece.

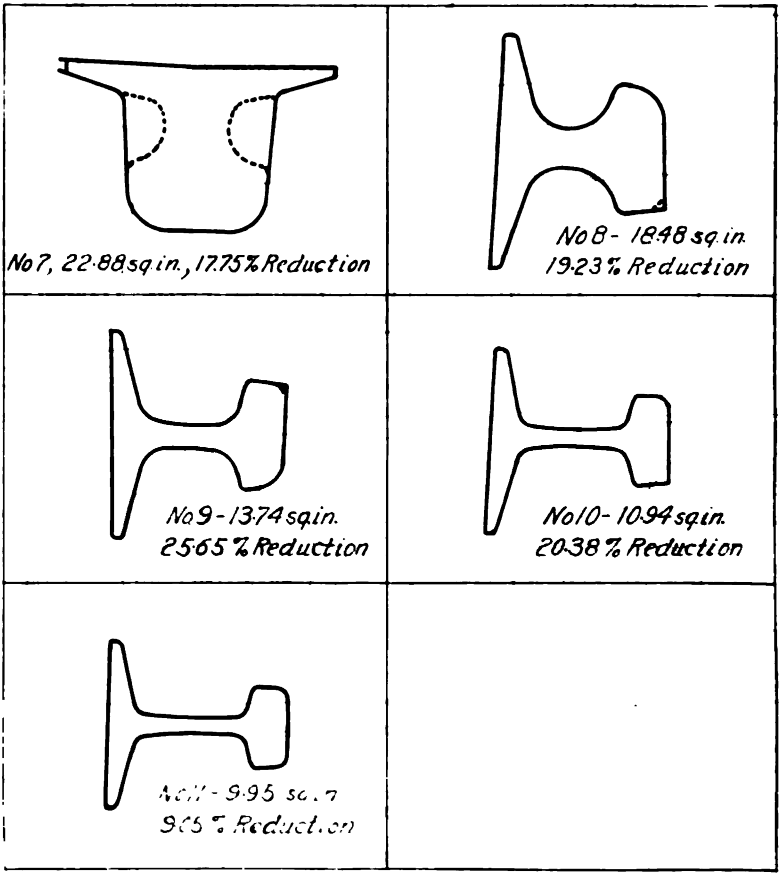

FIG. 2 —FINISHING PASSES.

TABLE 8—TEST PIECES RAIL-BAR 1—DISTANCE FROM TOP OF INGOT.

Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.
1 A 1	168	3.0	1 B 1	1,372	24.4	1 C 1	2,516	44.7
2	276	4.9	2	1,480	26.3	2	2,624	46.7
3	384	6.8	3	1,588	28.2	3	2,732	48.6
4	492	8.7	4	1,696	30.2	4	2,840	50.5
6	718	12.7	6	1,922	34.2	6	3,066	54.6
7	826	14.7	7	2,030	36.1	7	3,174	56.5
8	934	16.6	8	2,138	38.0	8	3,282	58.4
9	1,042	18.5	9	2,246	40.0	9	3,390	60.3
1 D 1	3,476	61.8	1 E 1	4,616	82.1			
2	3,584	63.8	2	4,724	84.0			
3	3,692	65.7	3	4,832	85.9			
4	3,800	67.6	4	4,940	87.9			
6	4,026	71.6	6	5,166	91.9			
7	4,134	73.5	7	5,274	93.8			
8	4,242	75.4	8	5,382	95.8			
9	4,350	77.4	9	.....	....			

TABLE 9—TEST PIECES RAIL-BAR 2—DISTANCE FROM TOP OF INGOT.

Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.
2 A 1	195	3.4	2 B 1	1,389	24.6	2 C 1	2,341	41.4
2	303	5.3	2	1,497	26.5	2	2,449	43.3
3	411	7.3	3	1,605	28.4	3	2,559	45.2
4	519	9.2	4	1,713	30.2	4	2,665	47.2
6	745	13.2	6	1,939	34.3	6	2,891	51.1
7	853	15.1	7	2,047	36.2	7	2,999	53.0
8	961	17.0	8	2,155	38.1	8	3,107	55.0
9	1,069	18.9	9	2,263	40.0	9	3,215	56.9
2 D 1	3,509	62.1	2 E 1	4,651	82.3			
2	3,617	64.0	2	4,759	84.2			
3	3,725	65.9	3	4,867	86.1			
4	3,833	67.8	4	4,975	88.0			
6	4,059	71.8	6	5,201	92.0			
7	4,167	73.7	7	5,309	94.0			
8	4,275	75.6	8	5,417	95.9			
9	4,383	77.5	9	.....	....			

TABLE 10—TEST PIECES RAIL-BAR 3—DISTANCE FROM TOP OF INGOT.

Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.
3 A 1	122	2.3	3 B 1	1,186	22.0	3 C 1	2,340	43.5
2	230	4.3	2	1,294	24.0	2	2,448	45.5
3	338	6.3	3	1,402	26.0	3	2,556	47.5
4	446	8.3	4	1,510	28.0	4	2,664	49.5
6	672	12.4	6	1,736	32.2	6	2,890	53.6
7	780	14.5	7	1,844	34.2	7	2,998	55.6
8	888	16.5	8	1,952	36.2	8	3,106	57.6
9	996	18.5	9	2,060	38.2	9	3,214	59.6
3 D 1	3,587	64.7	3 E 1	4,467	83.0			
2	3,595	66.7	2	4,575	85.0			
3	3,703	68.7	3	4,683	87.0			
4	3,811	70.7	4	4,791	89.0			
6	4,037	74.9	6	5,017	93.2			
7	4,145	76.9	7	5,125	95.1			
8	4,253	78.9	8	5,233	97.0			
9	4,361	81.0	9	.....	....			

TABLE 11—TEST PIECES RAIL-BAR 4—DISTANCE FROM TOP OF INGOT.

Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.	Test piece.	Lbs.	Per cent.
4 A 1	119	2.1	4 B 1	1,209	21.1	4 C 1	2,401	42.0
2	227	4.0	2	1,317	23.0	2	2,509	43.9
3	335	5.8	3	1,425	24.9	3	2,617	45.7
4	443	7.7	4	1,533	26.8	4	2,725	47.6
6	669	10.7	6	1,759	30.7	6	2,951	51.5
7	777	13.6	7	1,867	32.6	7	3,059	53.4
8	885	15.5	8	1,975	34.5	8	3,167	55.3
9	993	17.4	9	2,083	36.4	9	3.275	57.2
4 D 1	3,453	60.3	4 E 1	4,523	79.0			
2	3,561	62.2	2	4,631	80.9			
3	3,669	64.1	3	4,739	82.8			
4	3,777	66.0	4	4,847	84.6			
6	4,003	69.9	6	5,073	88.6			
7	4,111	71.8	7	5,181	90.5			
8	4,219	73.7	8	5,289	92.4			
9	4,327	75.5	9	5,397	94.2			

DROP TESTS.

Four drop tests were made of each rail, two with the head in tension and two with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were 3 ft. apart and the anvil was 20,000 lbs., spring supported. The striking surface of the tup and the bearing surfaces of the supports had radii of 5 in. The deflection in inches was measured after the first blow and was taken as the distance between a 3-ft. straight-edge and the part of the rail where struck by the tup. Gage marks one inch apart were put lengthwise on the side in tension, about the middle of the test piece, for a distance of 6 in., and the increase in length of the space which stretched most at failure was taken as the measure of the ductility of the rail. The results of the drop tests are shown in tables 12 to 15, inclusive.

TABLE 12—DROP TESTS RAIL-BAR I, BASIC STEEL, HOT BLOOM REHEATED.

No.	Per cent. from top of ingot.	Part in tension.	Deflection, first blow.	No. of blows.	Elongation, per cent.
1 A 2	4.9	Head	.98	2	8s
1 A 7	14.7	"	...	1	6
1 B 2	26.3	"	.90	2	8
1 B 7	36.1	"	.91	3	14
1 C 2	46.7	"	.97	3	16
1 C 7	56.5	"	.95	4	14
1 D 2	63.8	"	.95	3	17
1 D 7	73.5	"	.94	3	14
1 E 2	84.0	"	.97	3	16
1 E 7	93.8	"	1.00	3	14
Average			.95	2.7	12.7
1 A 4	8.7	Base	...	1	4
1 A 9	18.5	"	...	1	3s
1 B 4	30.2	"	...	1	5
1 B 9	40.0	"	.89	5	10
1 C 4	50.5	"	.86	5	10
1 C 9	60.3	"	.91	4	8
1 D 4	67.6	"	.90	5	13
1 D 9	77.4	"	.94	5	11
1 E 4	87.9	"	1.00	4	11
1 E 9	....		....	..	..
Average			.92	3.4	8.3
General average			.94	3.1	10.5

s means seam in bottom of base.

TABLE 13—DROP TESTS RAIL-BAR 2, BASIC STEEL, COLD BLOOM REHEATED.

No.	Per cent. from top of ingot.	Part in tension.	Deflection, first blow.	No. of blows.	Elongation, per cent.
2 A 2	5.3	Head	.95	3	15
2 A 7	15.1	"	.95	2	11
2 B 2	26.5	"	.95	3	15
2 B 7	36.2	"	.91	4	18
2 C 2	43.3	"	.91	4	17
2 C 7	53.0	"	.95	3	12s
2 D 2	64.0	"	.98	4	16
2 D 7	73.7	"	.98	3	16
2 E 2	84.2	"	.96	4	16
2 E 7	94.0	"	1.08	4	13
Average			.96	3.4	14.9
2 A 4	9.2	Base	...	1	4
2 A 9	18.9	"	.83	4	9
2 B 4	30.2	"	.88	5	15
2 B 9	40.0	"	.95	5	10
2 C 4	47.2	"	.83	6	14
2 C 9	56.9	"	.82	4	9
2 D 4	67.8	"	.95	5	12
2 D 9	77.5	"	.90	6	13
2 E 4	88.0	"	.91	5	9
2 E 9	....	..	...	..	..
Average			.88	4.6	10.6
General Average			.92	4.0	12.7

s means seam in bottom of base.

TABLE 14—DROP TESTS RAIL-BAR 3, ACID STEEL, HOT BLOOM REHEATED.

No.	Per cent. from top of ingot.	Part in tension.	Deflection, first blow.	No. of blows.	Elongation, per cent.
3 A 2	4.3	Head	1.08	3	17
3 A 7	14.5	"	1.10	4	21
3 B 2	24.0	"	1.16	3	17
3 B 7	34.2	"	1.12	4	19
3 C 2	45.5	"	1.18	5	21
3 C 7	55.6	"	1.19	4	24
3 D 2	66.7	"	1.17	4	21
3 D 7	76.9	"	1.20	3	11
3 E 2	85.0	"	1.15	4	16
3 E 7	95.1	"	1.14	4	21
Average			1.15	3.8	18.8
3 A 4	8.3	Base	1.10	4	10
3 A 9	18.5	"	1.05	4	11
3 B 4	28.0	"	1.09	5	12
3 B 9	38.2	"	1.09	5	13
3 C 4	49.5	"	1.11	5	15
3 C 9	59.6	"	1.10	5	11
3 D 4	70.7	"	1.08	5	12
3 D 9	81.0	"	1.08	4	11
3 E 4	89.0	"	1.08	4	10
3 E 9	....	..	....	..	..
Average			1.09	4.6	11.7
General Average			1.12	4.2	15.2

TABLE 15—DROP TESTS RAIL-BAR 4, ACID STEEL, COLD BLOOM REHEATED.

No.	Per cent. from top of ingot.	Part in tension.	Deflection, first blow.	No. of blows.	Elongation, per cent.
4 A 2	4.0	Head	1.20	4	24 L
4 A 7	13.6	"	1.15	4	20
4 B 2	23.0	"	1.21	2	10s
4 B 7	32.6	"	1.23	4	23
4 C 2	43.9	"	1.23	3	16s
4 C 7	53.4	"	1.19	4	14
4 D 2	62.2	"	1.15	5	23
4 D 7	71.8	"	1.22	4	22
4 E 2	80.9	"	1.14	4	19
4 E 7	90.5	"	1.15	5	20
Average			1.19	3.9	19.1
4 A 4	7.7	Base	1.21	5	16
4 A 9	17.4	"	1.19	5	12
4 B 4	26.8	"	1.11	5	12
4 B 9	36.4	"	1.12	4	15
4 C 4	47.6	"	1.15	4	..s
4 C 9	57.2	"	1.10	2	8s
4 D 4	66.0	"	1.08	5	13
4 D 9	75.5	"	1.14	4	11s
4 E 4	84.6	"	1.18	4	11s
4 E 9	94.2	"	1.15	2	5s
Average			1.14	4.0	11.4
General Average			1.17	4.0	15.3

L means interior lamination. s means seam in bottom of base.

Some seams in the base were developed in the drop test and these are listed in table 16.

TABLE 16—SEAMS IN BASE FOUND IN DROP TEST.

Rail-bar.	Test number.	Per cent. from top of ingot.	Depth of seam, inches.	Remark.
1	1 A 2	4.9	small	Basic steel, hot bloom.
1	1 A 9	18.5	.03	" " " "
2	2 C 7	53.0	small	Basic steel, cold bloom.
3	none found			Acid steel, hot bloom.
4	4 B 2	23.0	.14	Acid steel, cold bloom.
4	4 C 2	43.9	.03	" " " "
4	4 C 4	47.6	.06	" " " "
4	4 C 9	57.2	.08	" " " "
4	4 D 9	75.5	.06	" " " "
4	4 E 4	84.6	.12	" " " "
4	4 E 9	94.2	.03	" " " "

The average results of the drop tests for each of the rail-bars are collected together in table 17, showing the deflection after the first blow from 20 ft., the number of blows that it took to break the rail and the elongation measured after breaking.

TABLE 17—AVERAGE RESULTS IN DROP TEST.

	Basic Steel.		Acid Steel.	
	Hot Bloom.	Cold Bloom.	Hot Bloom.	Cold Bloom.
Rail-bar number	1	2	3	4
Carbon, per cent	.73	.73	.64	.63
Deflection, first blow, 20 ft.—				
Head tension	.95	.96	1.15	1.19
Base tension	.92	.88	1.09	1.14
Average	.94	.92	1.12	1.17
Number of blows—				
Head tension	2.7	3.4	3.8	3.9
Base tension	3.4	4.6	4.6	4.0
Average	3.1	4.0	4.2	4.0
Elongation, per cent.—				
Head tension	12.7	14.9	18.8	19.1
Base tension	8.3	10.6	11.7	11.4
Average	10.5	12.7	15.2	15.3

This work had reference particularly to the transverse ductility of the base of rail as regards acid steel compared with basic steel and as regards the effect of allowing blooms to become cold and then reheating them. It was desired to have the basic and acid steels of the same grade of hardness, but it turned out that the acid rails were softer than the basic, as shown by the carbon and the deflection given in the table. The acid rails showed more longitudinal ductility than the basic rails, but the difference was evidently due, in part at least, to the acid steel being softer. The largest number and deepest seams in the bottom of the base were found in the acid rails made from the reheated cold blooms.

Comparing the rails made from blooms that had been allowed to become cold and then reheated with those that had been rolled from hot blooms wash-heated directly after rolling into blooms, it will be noticed that, in the case of the basic rails, those from the reheated cold blooms stood more blows and gave greater elongation than those from the reheated hot blooms. The difference seems to have been largely in the samples from the upper third of the ingot. In the case of the acid rails the results averaged about the same. The rails from the reheated cold blooms showed a good many seams in the base, especially those from the lower part of the ingot, tested with the base in tension.

The elongation results of the four rail-bars are plotted in Fig. 3, the elongation being shown vertically and the distance from the top of the ingot in per cent. of the total weight being shown horizontally. For each

rail-bar one curve represents the results with the head in tension and another curve represents the results with the base in tension. The samples in which seams in the base were developed by the test are each indicated by an "s," and it will be noted that these samples were mostly of low ductility.

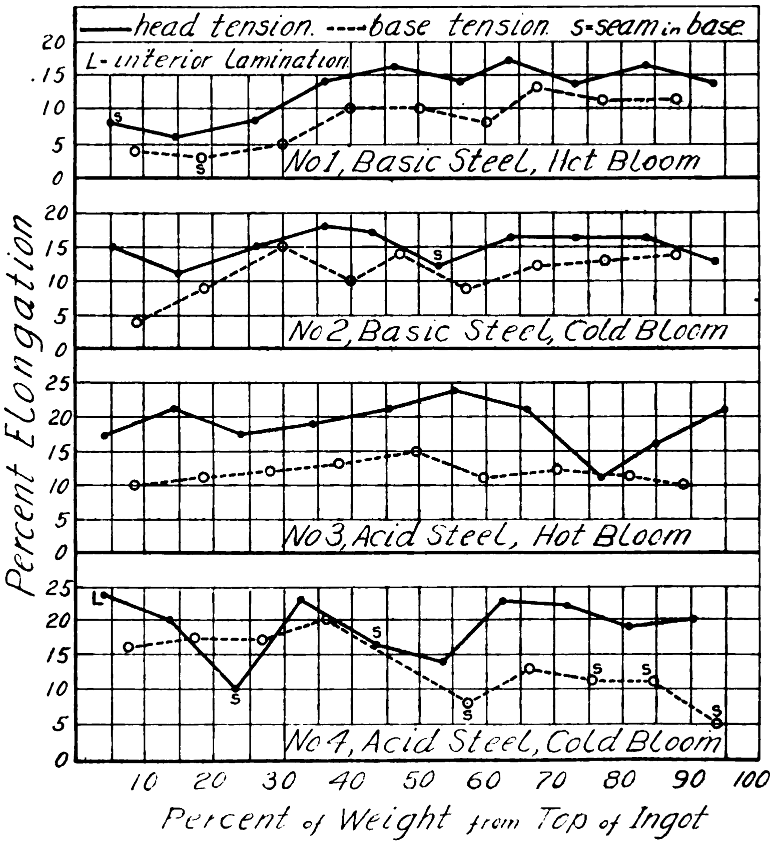

FIG. 3—ELONGATION IN DROP TEST IN RELATION TO DISTANCE FROM TOP OF INGOT.

While a definite conclusion is not possible from these few tests, the result is indicated that basic and acid open-hearth steels of the same grade of hardness give about the same results in the drop test. The result is also indicated that rails rolled from blooms allowed to become cold and reheated give about the same results in the drop test as rails rolled from blooms wash-heated directly after rolling into blooms from the ingot.

As interesting in this connection, I give some illustrations showing how a longitudinal seam in the bottom of the base may be the origin of a failure in the drop test before the longitudinal ductility of the rail is

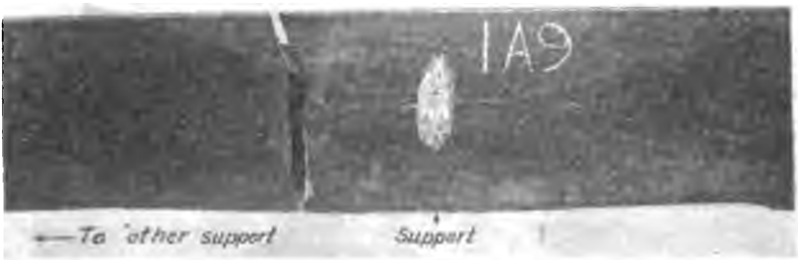

FIG. 4—SAMPLE OF RAIL TESTED WITH THE BASE IN TENSION IN THE DROP TEST, SHOWING HOW A SEAM IN THE BASE WAS THE ORIGIN OF A FAILURE.

FIG. 5—SIDE VIEW OF RAIL SHOWN IN FIG. 4.

FIG. 6—VIEW OF BASE OF RAIL TESTED WITH THE HEAD IN TENSION IN THE DROP TEST, SHOWING HOW A SEAM IN THE BASE OPENED WHERE STRUCK BY THE TUP, SPLITTING THE BASE.

exhausted. Fig. 4 shows the base of broken test piece 1 A 9, which was tested with the base in tension. The impression left on the base by the support was chalked to show up better in the picture. It will be noted

that the pressure of the rail on the support caused some side spread of the base at this place, which in turn opened up two seams. A piece of the flange broke and a fracture occurred through the whole section 3½

Fig. 7—Side View of Rail Shown in Fig. 6.

in. from the support, evidently as a secondary break. Fig. 5 shows a side view of the break through the section.

Fig. 6 shows the base of test piece 4 B 2, which was tested with the head in tension; that is, the head rested on the supports and the tup struck the base at about the middle of the piece. Here again it is seen that the indentation made by the tup spread the metal sideways, opening up a seam and causing the rail to split along the middle of the base. Fig.

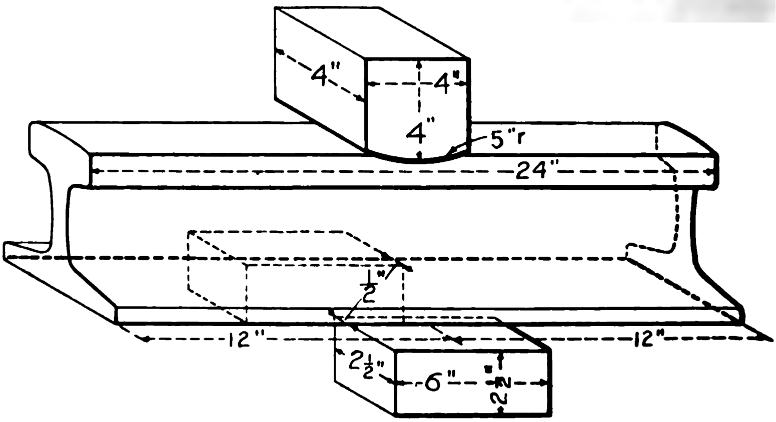

Fig. 8—Method of Making Transverse Test of the Base.

7 gives a side view of this rail after breaking. This failure evidently proceeded downward from the top side and not upward from the tension side.

TRANSVERSE TESTS OF BASE.

Transverse tests of the base were made of four pieces from each rail, each piece being two feet long. The method of making the test was to support the piece of rail on two supports placed opposite each other near the edges of the flanges under the middle of its length. The supports were six inches long and placed one-half inch in from the sides of the flanges and the load was applied in the test machine to the head of the rail at the middle. The general arrangement is shown by Fig. 8. These tests were made by the B. & O. R. R. in the laboratory at Baltimore. The load was measured that it took to break the rail. The transverse elongation was measured by putting a prick-punch mark on the center line of the base and then marking two one-inch spaces on each side of this crosswise on the bottom of the base and at the middle of the length of the

FIG. 9—SAMPLES OF RAIL AFTER MAKING TRANSVERSE TEST OF BASE.

piece tested. The greatest extension after breaking, in any one of the four spaces, was taken as the measure of transverse ductility. The sag of the unbroken flange was measured and was taken as the distance from a straight-edge laid on the bottom of the base near the edge of the unbroken flange to the flange where bent most from the straight surface of the base. Some of the pieces showed seams (mostly dark) in the bottom of the base and their depths were measured. The distance of the break from the center line of the base was measured and whether above or below the center of the base as rolled was noted. In the tables of results "a" means above and "b" means below.

A few samples of the various types of fracture are shown in Fig. 9, from which it will be noted that in some cases a short curved piece broke out of the flange, while in other cases a long piece was broken out with

a long straight break at or near the middle of the base. A sample of the seams found in some of the pieces is shown in Fig. 10.

The results of the transverse tests of the base are shown in tables 18 to 21, inclusive.

FIG. 10—VERTICAL LONGITUDINAL FRACTURE OF FLANGE, SHOWING LONGITUDINAL SEAM IN BOTTOM OF BASE.

TABLE 18—TRANSVERSE TESTS RAIL-BAR 1, BASIC STEEL, HOT BLOOM REHEATED.

No.	Per cent. from top of ingot.	Load, pounds.	Transverse elongation, per cent.	Sag, inches.	Depth of seam, inches.	Break from center, inches.
1 A 1	3.0	186,300	0	...	...	.03a
1 A 3	6.8	185,300	0	.03	.04	.22b
1 A 6	12.7	140,400	0	.01	.03	.50b
1 A 8	16.6	139,800	1	.02	...	.08b
1 B 1	24.4	234,400	1	.06	...	.80b
1 B 3	28.2	233,200	1	.07	...	.08b
1 B 6	34.2	249,000	1	.06	...	.02b
1 B 8	38.0	200,900	1	.02	...	.26a
1 C 1	44.7	224,300	2	.03	...	.10a
1 C 3	48.6	175,000	0	.04	.03	.16a
1 C 6	54.6	295,300	2	.12	...	.60a
1 C 8	58.4	283,200	2	.10	...	.96b
1 D 1	61.8	254,600	2	.08	...	.38a
1 D 3	65.7	215,600	1	.03	...	.54b
1 D 6	71.6	256,000	2	.05	...	.62b
1 D 8	75.4	248,500	1	.05	...	.25a
1 E 1	82.1	201,200	1	.03	.04	.12a
1 E 3	85.9	282,000	2	.14	...	.08a
1 E 6	91.9	297,000	3	.17	...	.73a
1 E 8	95.8	286,000	2	.12	...	.52b
Average		229,400	1.3	.065		

TABLE 19—TRANSVERSE TESTS RAIL-BAR 2, BASIC STEEL, COLD BLOOM REHEATED.

No.	Per cent. from top of ingot.	Load, pounds.	Transverse elongation, per cent.	Sag, inches.	Depth of seam, inches.	Break from center. inches.
2 A 1	3.4	235,200	1	.04	...	.16a
2 A 3	7.3	180,200	1	.02	...	.60b
2 A 6	13.2	171,000	1	.02	.04	.18b
2 A 8	17.0	149,400	0	.02	...	.25a
2 B 1	24.6	271,400	2	.08	...	1.00b
2 B 3	28.4	165,800	0	.03	.04	.16b
2 B 6	34.3	167,400	0	.02	.04	.20a
2 B 8	38.1	216,100	1	.04	...	.16a
2 C 1	41.4	209,000	1	.00	...	.48a
2 C 3	45.2	269,200	2	.08	...	.06a
2 C 6	51.1	200,800	1	.03	.03	.12a
2 C 8	55.0	150,700	1	.00	.03	.34a
2 D 1	62.1	276,500	2	.06	...	1.10a
2 D 3	65.9	231,000	1	.07	...	.35a
2 D 6	71.8	246,900	1	.06	...	.18a
2 D 8	75.6	252,600	1	.03	...	.30a
2 E 1	82.3	260,000	1	.05	...	.24a
2 E 3	86.1	245,700	2	.06	...	.50b
2 E 6	92.0	301,600	3	.20	...	.64a
2 E 8	95.9	296,600	2	.15	...	.66b
Average	....	224,855	1.2	.058		

TABLE 20—TRANSVERSE TESTS RAIL-BAR 3, ACID STEEL, HOT BLOOM REHEATED.

No.	Per cent. from top of ingot.	Load, pounds.	Transverse elongation, per cent.	Sag, inches.	Depth of seam, inches.	Break from center. inches.
3 A 1	2.3	243,600	2	.10	...	.92a
3 A 3	6.3	222,700	1	.08	...	.64b
3 A 6	12.4	242,100	2	.07	...	.96b
3 A 8	16.5	213,400	1	.04	...	.03b
3 B 1	22.0	225,600	1	.09	...	.34a
3 B 3	26.0	263,000	2	.14	...	.00
3 B 6	32.2	242,700	2	.06	...	.14b
3 B 8	36.2	242,100	2	.12	...	1.25a
3 C 1	43.5	175,800	0	.03	...	.52a
3 C 3	47.5	266,100	2	.11	...	.58b
3 C 6	53.6	239,600	2	.10	...	1.22a
3 C 8	57.6	193,600	1	.04	...	.96b
3 D 1	64.7	255,200	3	.16	...	.40a
3 D 3	68.7	224,700	1	.06	...	.46a
3 D 6	74.9	244,800	1	.15	...	.26b
3 D 8	78.9	236,000	2	.06	...	1.15a
3 E 1	83.0	158,200	1	.01	.06	.00
3 E 3	87.0	268,600	2	.13	...	.40a
3 E 6	93.2	206,000	1	.08	..	1.04b
3 E 8	97.0	185,300	1	.02	.04	.16b
Average		227,455	1.5	.083		

TABLE 21—TRANSVERSE TESTS RAIL-BAR 4, ACID STEEL, COLD BLOOM REHEATED.

No.	Per cent. from top of ingot.	Load, pounds.	Transverse elongation, per cent.	Sag, inches.	Depth of seam, inches.	Break from center, inches.
4 A 1	2.1	239,100	2	.06	...	.70a
4 A 3	5.8	197,200	1	.03	...	.84a
4 A 6	10.7	224,000	1	.07	...	.66a
4 A 8	15.5	218,500	1	.04	...	1.12a
4 B 1	21.1	157,300	0	.03	...	1.10a
4 B 3	24.9	256,600	2	.10	...	.76a
4 B 6	30.7	230,400	1	.04	...	.50a
4 B 8	34.5	274,100	2	.22	...	.60a
4 C 1	42.0	208,000	2	.08	...	.42b
4 C 3	45.7	218,900	1	.07	...	.16b
4 C 6	51.5	177,100	1	.04	.04	.20b
4 C 8	55.3	209,000	2	.15	...	.25b
4 D 1	60.3	191,800	0	.06	.01	.12b
4 D 3	64.1	159,600	0	.00	.02	.54b
4 D 6	69.9	72,700	0	.05	.06	1.12a
4 D 8	73.7	172,300	1	.05	.08	.50
4 E 1	79.0	264,300	2	.15	...	.16a
4 E 3	82.8	196,800	0	.04	.04	.16a
4 E 6	88.6	205,300	2	.05	...	.74a
4 E 8	92.4	216,500	2	.07	.03	.08a
Average		204,475	1.2	.070		

The average results in the transverse tests of the base are collected together in table 22, showing the breaking load, the transverse elongation and the sag of flange.

TABLE 22—AVERAGE RESULTS IN TRANSVERSE TESTS OF BASE.

	Basic Steel.		Acid Steel.	
	Hot Bloom.	Cold Bloom.	Hot Bloom.	Cold Bloom.
Load, lbs.	229,400	224,855	227,455	204,475
Elongation, per cent.	1.3	1.2	1.5	1.2
Sag of flange, inches	.065	.058	.083	.070

Comparing the rails made direct from the wash-heated blooms with those from the reheated cold blooms, it will be noted that the breaking load and the ductility were a little greater in the rails rolled direct from the wash-heated blooms.

The results showing the breaking load are plotted in Fig. 11 for each of the rail-bars, the distance from the top of the ingot in per cent. of the weight being shown horizontally and the breaking load in pounds, vertically. Each piece in which a seam was found in the bottom of the base is indicated by an "s." It will be noted that the breaking load was rather irregular along the bar and that in most cases where a seam was found the load was low.

The results showing the sag of flange are plotted in Fig. 12 for each of the rail-bars in a manner similar to the breaking load results. Here again we see considerable irregularity of the results along the bar.

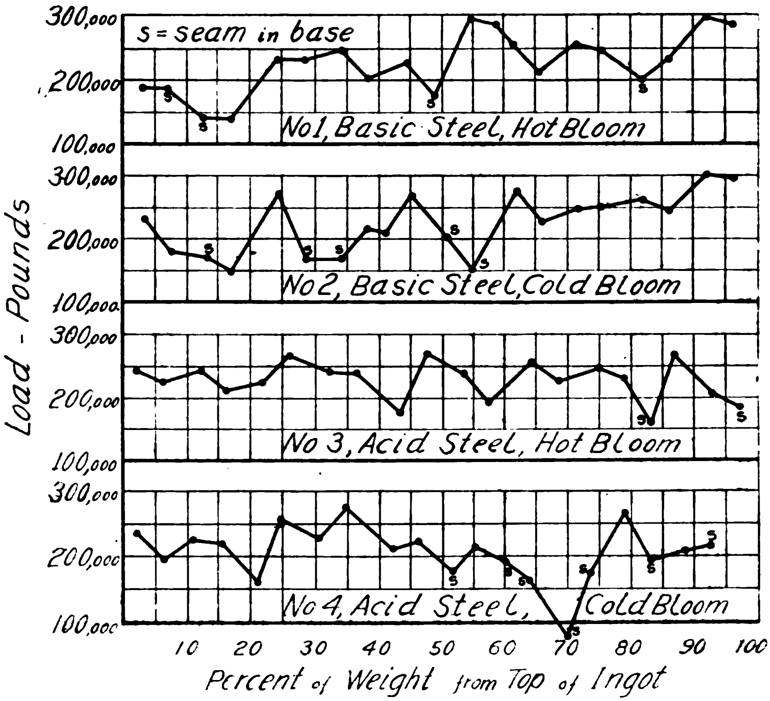

FIG. 11—BREAKING LOAD IN TRANSVERSE TEST OF BASE IN RELATION TO DISTANCE FROM TOP OF INGOT.

To show up the effect of a seam on the breaking load and the sag of the flange, Fig. 13 is given, in which the depth of seam is plotted horizontally and the load and sag of flange, vertically. It will be noted that a seam of say .06 or 1-16 inch deep was attended with a decrease in transverse strength of about 35 per cent. and a decrease of sag of flange of about 75 per cent.

Fig. 14 is given to show the location on the base of rail, of the fracture in the transverse test of the base, and particularly its distance from

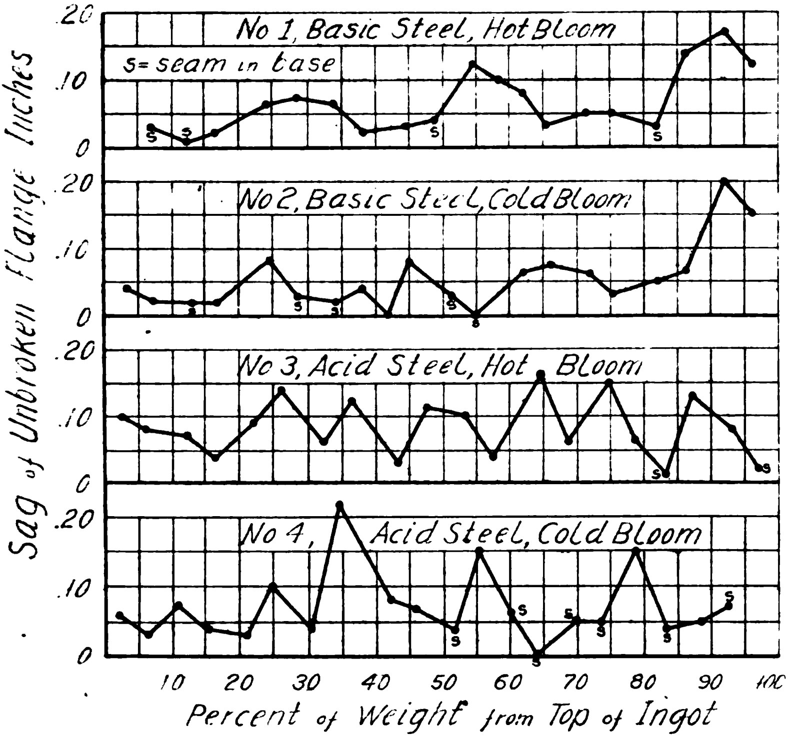

FIG. 12—SAG OF FLANGE IN TRANSVERSE TEST OF BASE IN RELATION TO DISTANCE FROM TOP OF INGOT.

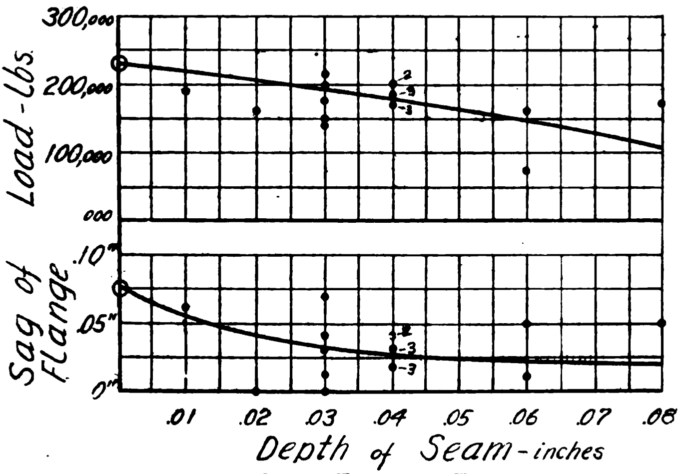

FIG. 13—BREAKING LOAD AND SAG OF FLANGE IN TRANSVERSE TEST OF BASE IN RELATION TO DEPTH OF SEAM.

the center line of the base. The figure gives a diagram for each rail-bar and in general it may be said that the fractures occurred irregularly either side of the center line of the base and at varying distances from the center.

SUMMARY.

1. An investigation was made comparing rails made of acid open-hearth steel with rails made of basic open-hearth steel and also concerning the influence on rails of reheating blooms that had been allowed to become cold. Two ingots were taken of a regular rail heat of basic open-hearth steel, one ingot bloomed and the hot bloom put through a reheating

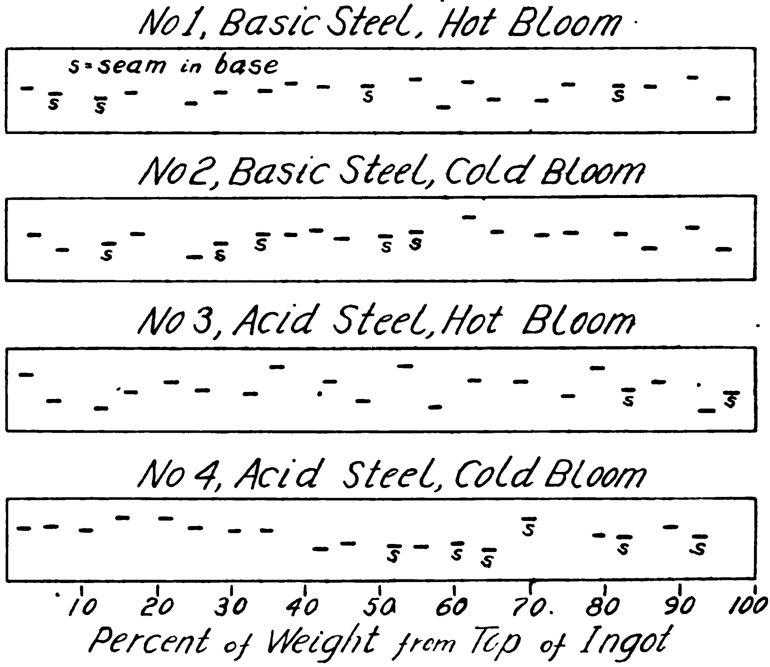

FIG. 14—LOCATIONS OF BREAKS IN TRANSVERSE TEST OF BASE.

furnace or given a "wash" heat and then rolled into 100-lb. rails. The other ingot was bloomed, the bloom allowed to become cold, reheated the next day and then rolled into rails of the same section. Two similar ingots were taken from a heat of acid open-hearth steel and handled in the same manner as the basic ingots. The rails were then cut up for drop tests and transverse tests of the base, the purpose of the work being primarily to compare the transverse properties of the base.

2. The work was done mostly at Steelton, Pa., at the works of the Pennsylvania Steel Co., who kindly furnished the material and most of the facilities for the investigation. The transverse tests of the base were

made at Baltimore, Md., at the laboratory of the Baltimore & Ohio R. R., who kindly made the tests, as the test machines at Steelton were not of sufficient capacity for this work.

3. It was desired to have the basic and acid steel of the same composition, but the final results showed the basic rails to contain .73 per cent. carbon and the acid rails to contain .64 per cent. carbon, or .09 per cent. more in the basic rails.

4. In the drop test, the acid rails showed more longitudinal ductility than the basic rails, but the difference was evidently due, in part at least, to the acid steel being softer.

5. Rails rolled from blooms allowed to become cold and reheated gave about the same results in the drop test as rails rolled from blooms wash-heated directly after rolling into blooms from the ingot.

6. An example is given of a piece of rail with a seam in the base that was tested in the drop machine in the usual manner as a girder with the base in tension, and in which the longitudinal seam was evidently the origin of a failure before the longitudinal ductility was exhausted. In brief, the explanation seems to be that the cross-spread of the metal at one of the supports opened up a seam, which crack then resulted in a failure through the whole section, several inches from the support. An example is also given of a rail tested with the head in tension, where a longitudinal seam in the base appeared to be the origin of the failure, due to the cross-spread of the base where struck by the tup opening up a seam at this point.

7. Transverse tests of the base were made by supporting pieces of rail 2 ft. long on two supports placed opposite each other near the edges of the flanges under the middle of the length of the piece tested. The supports were six inches long and were placed one-half inch in from the sides of the flanges. The load was applied in the test machine to the head of the rail at the middle.

8. In the transverse test of the base the basic and acid rails gave about the same results. Rails rolled from wash-heated hot blooms gave a little greater ductility and breaking load than the rails from reheated cold blooms and more base seams were found in the rails from reheated cold blooms.

9. In the transverse test of the base the presence of a longitudinal seam in the base of 1-16 inch deep was attended with a reduction of about 35 per cent. in the breaking load and about 75 per cent. in the sag of the flange when broken.

10. Finally it may be said that this investigation was not extensive enough to show up small differences, but in a general way rails from basic open-hearth steel and from acid open-hearth steel gave about the same results in the drop test and the transverse test of the base. Also rails from reheated cold blooms gave about the same results as rails from wash-heated hot blooms.

INFLUENCE OF SEAMS OR LAMINATIONS IN BASE OF RAIL ON DUCTILITY OF METAL

(Second Paper)

INCLUDING

A STUDY OF DIFFERENT RAIL BASES

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In Report No. 27 of July, 1912, to the Rail Committee of the American Railway Engineering Association,* it was shown that the influence of seams or laminations in the bases of rails was a most important factor in rail failures.

It was shown that the presence of seams in rails as rolled had a decided weakening effect on the strength of the base. Data were not produced, however, to show what physical properties of the steel were changed on account of seams or laminations in the rail.

As a result of the information obtained in the preliminary investigation and the discussions following the publication of the above mentioned Bulletin, the investigation along lines suggested from analysis of results obtained was continued in order to establish more definite data on the subject.

The specimens for previous test were invariably subjected to transverse tests, which involve tension in one part of the section and compression in the other. Inasmuch as there is more data available, relative to physical qualities of metal under tension than under compression, it was thought advisable to secure complete data as to the strength and ductility of the base of the rail under tension and from this data to determine whether there is not a considerable decrease in the ductility of the metal due to laminations contained therein.

Particular consideration was given to developing information with the following objects in view:

*Bulletin Am. Ry. Eng. Assn. No. 147, Vol. 14, July, 1912, pages 315-334. Also Proceedings Am. Ry. Eng. Assn., 1913, Vol. 14, pages 315-334.

Report No. 36, April, 1913.

1. To determine the number, depth and extent of seams in the base of the rail by taking etched sections at definite intervals along the length of the rail base and measuring the seam at the fracture for depth.

2. To determine whether or not the weakening influence due to seams was proportional with different thicknesses of metal, that is, if the same per cent depth of seams would produce the same per cent reduction of strength in varying thicknesses of metal. This with an object of determining whether or not the weakening influence of seams might be lessened by increasing the thickness of base should it be necessary to resort to such practice on account of impracticability of eliminating seams.

3. To determine the effect of seams on the ductility of the metal, not only in tensile tests where all the metal is in tension, but also in transverse tests, simulating service conditions where part of the metal is in compression.

4. To determine the effect of low temperatures on the ductility and strength of section of base of rail.

5. To determine the effect of sudden or repeated blows with an initial load on rail.

FIG. 1—Short sections of failed rails showing the character of fracture resulting from the base failures.

The progress of the investigation suggested the following additional lines of investigation:

6. To determine the relative strength of the specimens taken crosswise and longitudinal to base of rail—the variation in strength, if any, of surface metal and interior metal.

7. To determine the relative strength in transverse tests of different types of rail-base sections.

CHARACTERISTIC BASE FAILURES.

Figure 1 shows five different rails with characteristic square and angular breaks, all of which show indications of seams in the base. Figure 2 shows seven failed rails of lengths varying from 5 to 8 ft. These rails show typical half-moon base failures. The failures occur sometimes on one side of the rail and sometimes on the other, but almost invariably completely or partially under the tie plate.

RAILS FOR INVESTIGATION.

The six rails for special investigation were selected from a lot of failed rails that had been sent to the laboratory for test. This lot included rails from different manufacturers, of different section and of

FIG. 2—Showing base failures existing in rails, typical of the half-moon base failure. It is evident that the failure, as a rule, occurs on or near the edge of a tie, and these rails show the distinct marks of the tie plate. These base failures precede square or angular breaks in about 90 per cent of failed rails sent into the laboratory for investigation.

different weight. Three weights of rails were investigated—75, 85 and 90 lb. rails. Three different rail sections were investigated—ASCE, ARA and Santa Fe. The rails investigated came from four different manufacturers—Illinois Steel Company, Maryland Steel Company, Colorado Fuel & Iron Company and Lackawanna Steel Company.

In selecting the rails for investigation, no particular regard was given to the manufacturer, the principal idea was to secure specimens with dissimilar failures in order to determine whether or not the seams and laminations such as found in the base of rails failing with characteristic half-moon base failures and with square and angular breaks, could be traced through all rails.

In Table 1 the general data relative to the rails selected for investigation are shown:

TABLE 1—GENERAL DATA ON RAILS TESTED.

Lab. No.	Weight Pounds.	Section.	Manufacturer.	Date Rolled.	Failure.
10062	85	ASCE	Illinois Steel Co. South Works	1904	Square with half moon.
12101	85	ASCE	Maryland Steel Co.	5-07	Square with half moon.
15018	90	Santa Fe	Illinois Steel Co. Gary	11-09	Web.
17045	75	ASCE	C. F. & I. Co.	....	Derailment.
10057	90	Santa Fe	Lackawanna Steel Co. Buffalo	12-09	Angular.
33015	85	ARA	C. F. & I. Co.	11-08	Head.

A chemical analysis of the rails gave results as shown in Table 2:

TABLE 2—CHEMICAL ANALYSIS OF RAILS.

Rail No.	C.	P.	S.	Mn.	Si.
10062	.61	.082	.058	.89	.12
12101	.61	.086	.043	.65	.04
15018	.69	.051	.030	.74	.16
17045	.57	.114	.036	1.03	.17
20057	.57	.089	.054	.78	.15
33015	.61	.085	.045	.82	.07

From this analysis, it will be seen that all of the rails with the exception of the 90-lb. rail from the Gary plant of the Illinois Steel Company, were of Bessemer steel. One of the rails, that from the Lackawanna Steel Company, was a titanium rail. The rest of the rails represented a very large percentage of tonnage of rails now in track service on the A., T. & S. F. Ry. System.

The relative hardness of the different rails under investigation, as shown by the scleroscope, is shown in Table 3:

TABLE 3—SCLEROSCOPE HARDNESS OF RAIL BASE SECTIONS.

Readings made each square quarter inch, base section only.

		Hardness.		
Laboratory No.	Section.	Maximum.	Minimum.	Average.
10062	A	42	41	41.8
	C	42	41	41.3
	E	42	41	41.4
	Average			41.5
12101	A	42	40	41.2
	C	42	40	41.3
	Average			41.25
15018	A-1	46	42	44.5
	B-2	44	42	42.8
	C-1	44	41	42.9
	C-2	45	42	43.3
	Average			43.4
17045	A	42	40	41.4
	B	43	40	41.1
	Average			41.3
20057	A	43	40	41.8
	B	43	41	41.9
	Average			41.9
33015	A-1	50	35	42.2
	A-2	52	37	41.2
	B-1	52	35	44.6
	C-2	48	35	42.1
	Average			42.5

PREPARATION OF SPECIMENS.

The base only was to be investigated for reasons before given, accordingly it was considered advisable to have the base of the rail cut off at the junction of the web in order to expedite the work. One edge of the base was then center punched about every half inch in order that all measurements might be made from the same edge. The base was then cut into sections varying from 2 to 4 ft. in length. These sections were stenciled A, B, C and so forth in regular order. The location of specimens may be best understood by referring to the diagram, Fig. 3. All the specimens were numbered regularly and lettered to indicate the section from which taken.

Inasmuch as this investigation includes tensile tests on metal at the surface and also tensile tests on metal within the surface, those

specimens which had base surface removed are referred to as sections with bases planed, while sections which did not have base surface removed are spoken of as specimens with surface or base natural.

Almost invariably every even numbered specimen had the base planed off to eliminate, if possible, the influence of seams in the base.

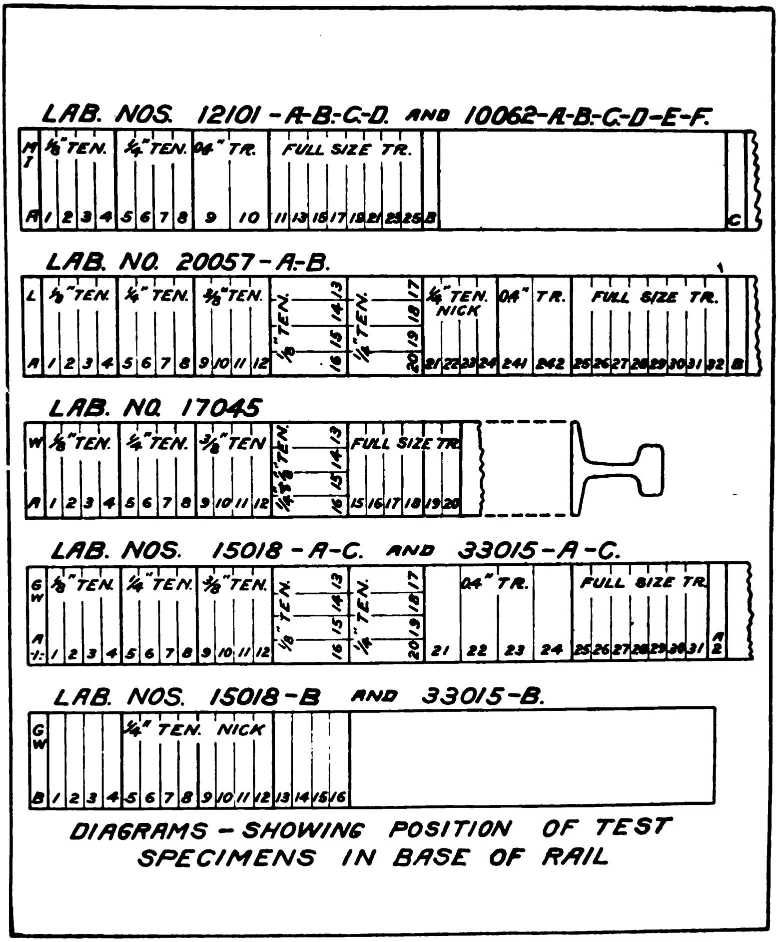


FIG. 3.

As a general rule it may be stated that the odd numbered specimens are with base surface as rolled and the even numbered specimens are with base surfaces planed. The exceptions are specimens 17 and 19, of A, B, C and D sections of rail 12101, and specimens 21 and 23, C and D sections same rail, which had both surfaces planed. Specimens 1 to 8, in-

clusive, rail 15018, section B, have base natural, while specimens 9 to 16, inclusive, section B, have both surfaces planed. Specimens 1 to 8, inclusive, of rail 33015, section B, have both surfaces planed, while specimens 9 to 16, inclusive, of same section have base surfaces natural. Sections A, B, C, D and E, specimens 17 and 19, of rail 10062, and specimens 21 and 23 of sections C, D and E of the same rail had both surfaces planed.

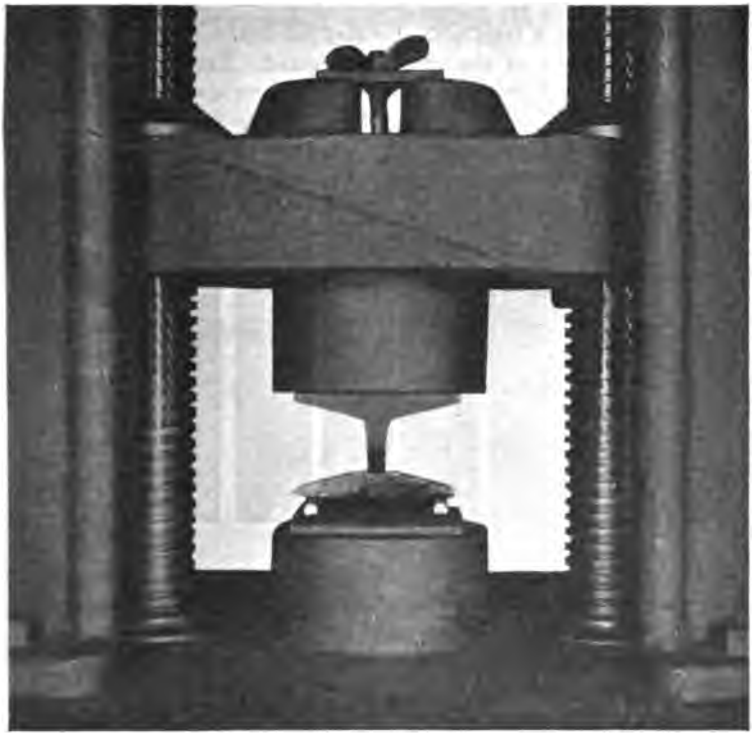


FIG. 4—Showing method of testing transverse specimens. Loading at center and supporting at each edge on one-half inch round steel lying in grooves of plate. Four-inch spans. Load being applied through base of separate rail.

Three different sizes of tension test specimens were used in this investigation with dimensions approximately as follows: 1"x⅛"; 1"x¼", and 1"x⅜". All tension test specimens were 2 in. between punch marks.

Two sizes of transverse specimens were taken as follows: 2"x0.4" and 1 in. by full heighth of base, varying from approximately 0.8 to 1 in. All transverse base specimens were broken as beams loaded at the center

with 4-in. spans. The method of setting up transverse test specimens in the testing machine is shown in Fig. 4.

The test sections were reduced in width at middle portion so as to prevent, as much as possible, the specimens from breaking in the jaws of the testing machine. The tension test specimens were gripped in the flat jaws of the machine and pulled in accordance with standard practice.

RESULTS.

Ordinary tension tests with standard one-half inch tension specimens were made on two of the rails investigated. These rails in question showed very close chemical analysis except for manganese and silicon content. The results of tension tests are given in Table 4:

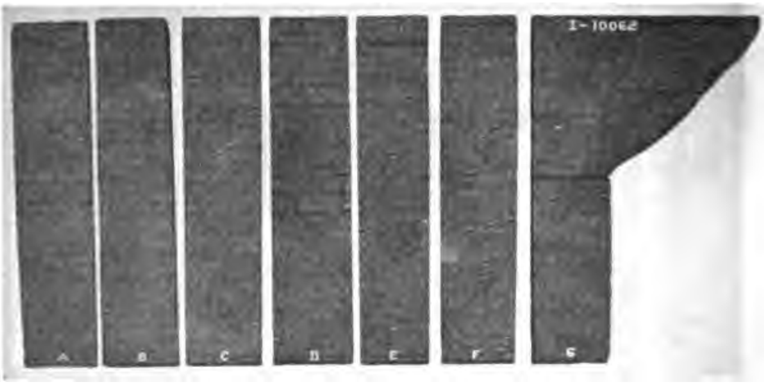


FIG. 5—Showing the base of rail 10062, sections 2 ft. apart. Section A at end of rail. Note the almost entire absence of seams in section A, and the well developed seam in section G.

TABLE 4—TENSILE PROPERTIES OF RAILS.

	Rail Number. F-10062.	E-12101.
Elastic limit, lbs. per square inch	66,200	77,100
Ultimate strength, lbs. per square inch	120,000	118,900
Elongation in 2 in., per cent	16.0	13.5
Reduction in area, per cent	28.4	17.6

The physical nature of specimens investigated and some of the results of investigation are shown in Figs. 5 to 34, inclusive. Figures 5, 12, 18, 21 and 25 show sections, 2 to 4 ft. apart, of base of rails investigated. The rail base has been etched to bring out the seams. Specimen *A* in each instance is the end of the rail. It will be noted that, although in some cases the seams are not clearly defined in the end, or *A* specimen,

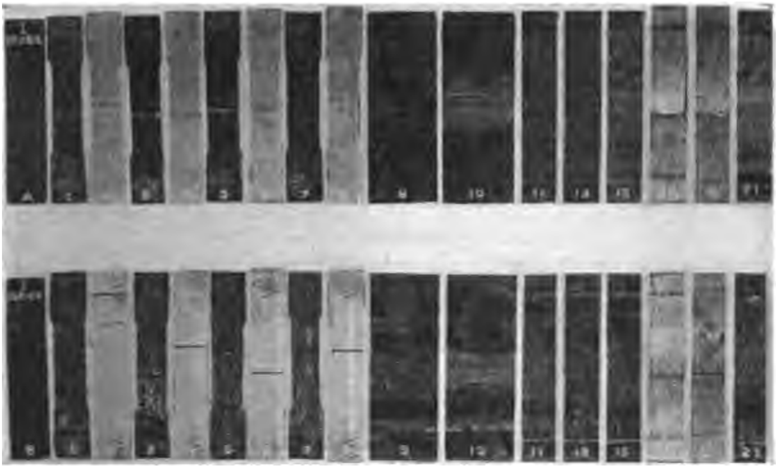


FIG. 6—Showing tension and transverse test specimens of A and B sections rail 10062, after test. Specimens 1 to 8, inclusive, tension test specimens. Specimens 9 to 21, inclusive, transverse test specimens.

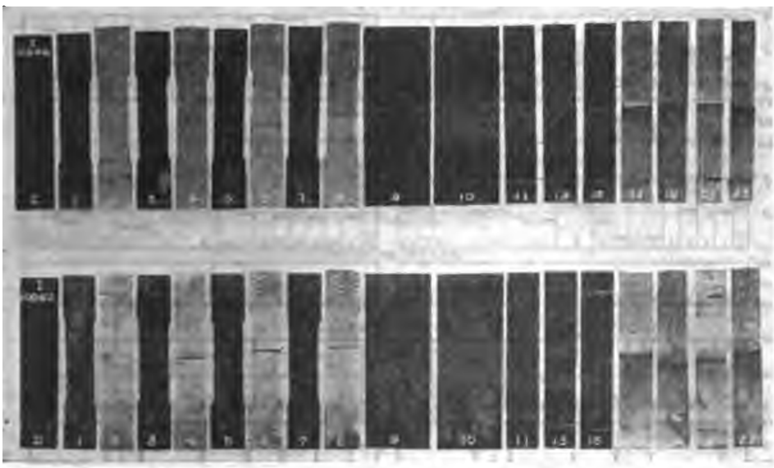


FIG. 7—Showing manner of failure of tension and transverse test specimens, sections C and D, rail 10062. Specimens 1 to 8, inclusive, tension test specimens. Sections 9 to 23, inclusive, transverse test specimens.

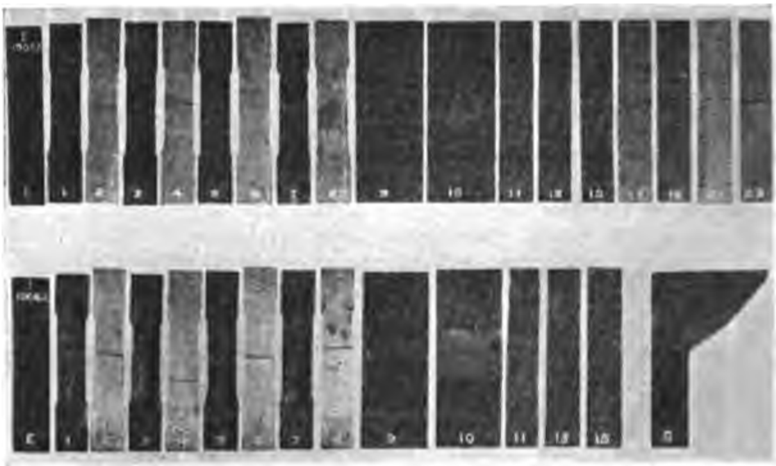


FIG. 8—Showing tension and transverse test specimens after test, sections E and F, rail 10062. Specimens 1 to 8, inclusive, tension test specimens. Specimens 9 to 23, inclusive, transverse test. Note the manner in which the failures followed along lines of well defined seams.

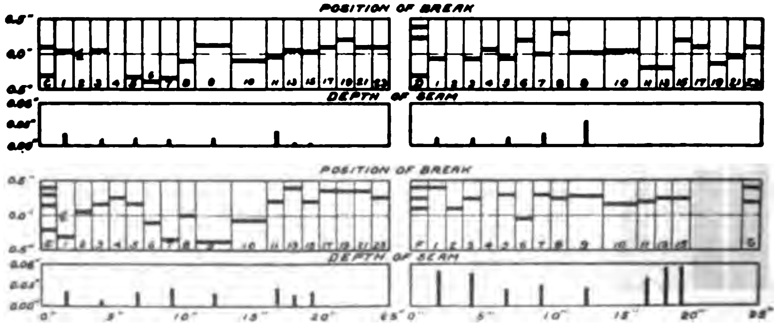


FIG. 9—Showing by heavy lines occurrence of seams in A, B, C, D, E and F portions of rail one-half inch either side of middle line of base and by heavy line position of break. Depth of seam at break shown under each test piece.

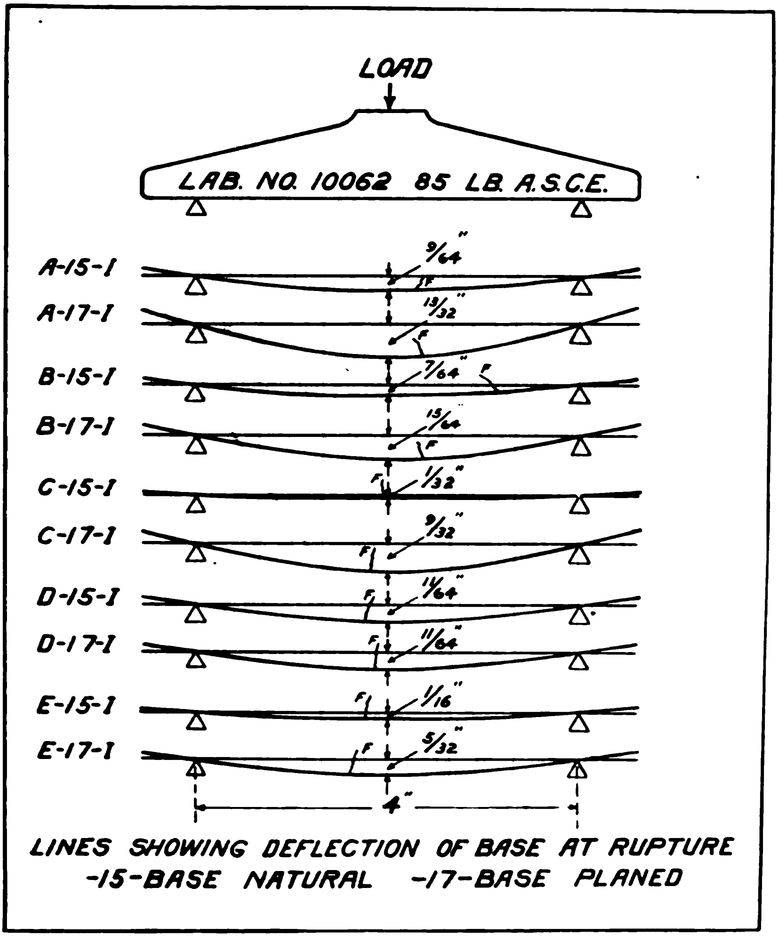

LOAD
LAB. NO. 10062 85 LB. A.S.C.E.
A-15-1
9/64"
A-17-1
13/32"
B-15-1
7/64"
B-17-1
15/64"
C-15-1
1/32"
C-17-1
9/32"
D-15-1
11/64"
D-17-1
11/64"
E-15-1
1/16"
E-17-1
5/32"
4"
LINES SHOWING DEFLECTION OF BASE AT RUPTURE
-15-BASE NATURAL -17-BASE PLANED

FIG. 10.

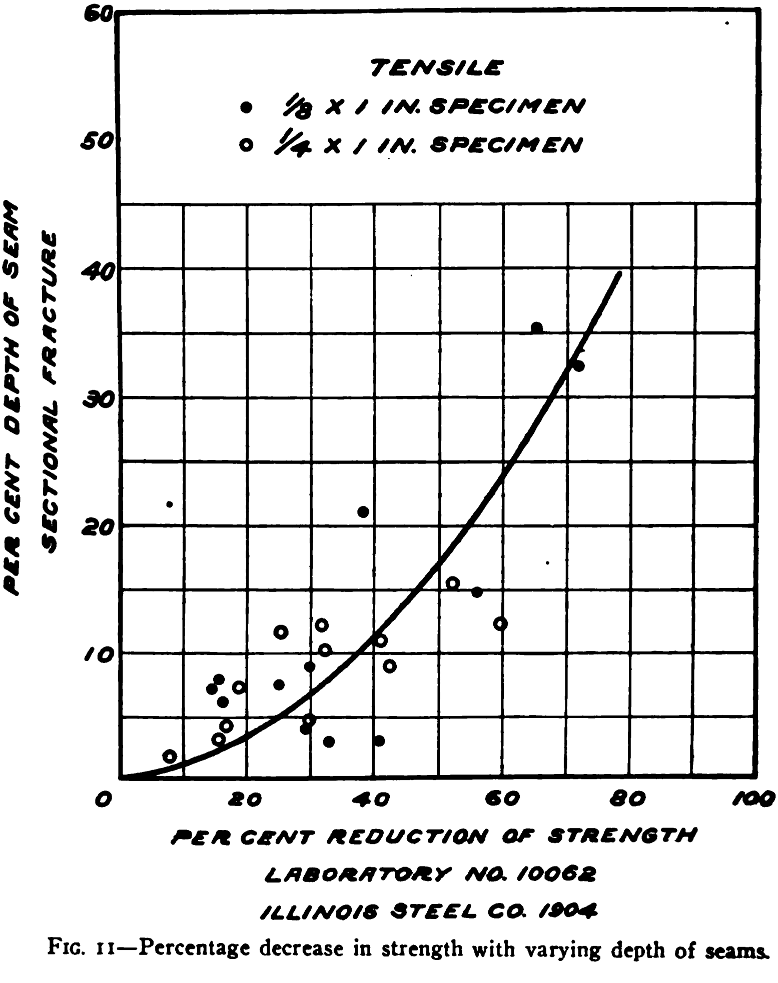


FIG. 11—Percentage decrease in strength with varying depth of seams.

FIG. 12—Sections from base of rail 12101, showing base etched to bring out seams. Sections 2 ft. apart. Note the slight seams in specimen A, at end of rail, and the more pronounced development towards the middle of the rail.

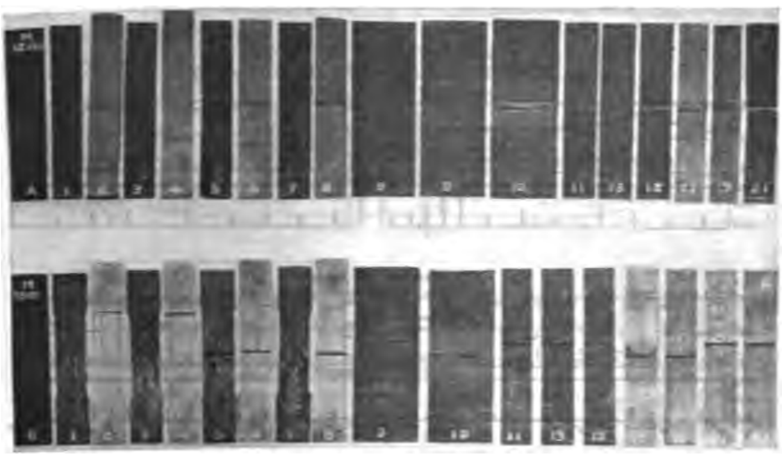


FIG. 13—Showing tension and transverse test specimens of A and B section rail 12101 after test. Specimens 1 to 8, inclusive, tension test; specimens 9 to 23, inclusive, transverse test.

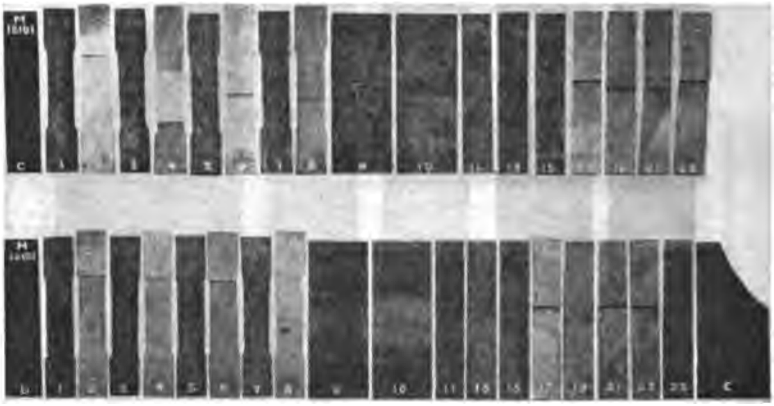


FIG. 14—Showing tension and transverse test specimens of C and D sections of rail 12101 after test. Specimens 1 to 8, inclusive, tension test; specimens 9 to 25, inclusive, transverse test.

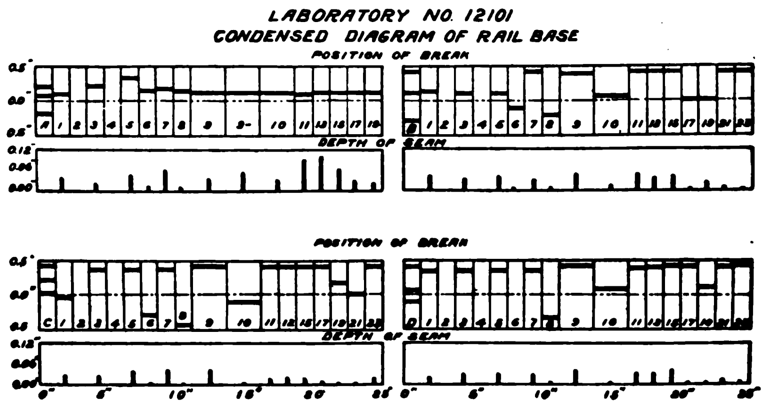


FIG. 15—Showing relation of fracture to seams in middle portion of base.

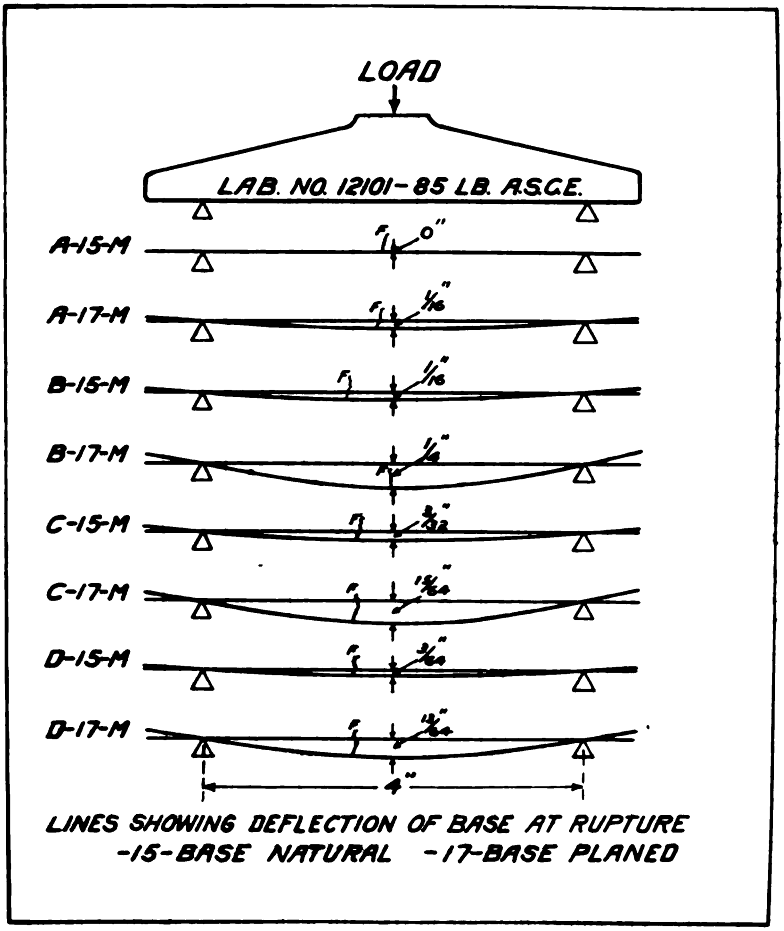

LOAD
LAB. NO. 12101-85 LB. A.S.C.E.
A-15-M
A-17-M
B-15-M
B-17-M
C-15-M
C-17-M
D-15-M
D-17-M
4"
LINES SHOWING DEFLECTION OF BASE AT RUPTURE
-15-BASE NATURAL -17-BASE PLANED

FIG. 16.

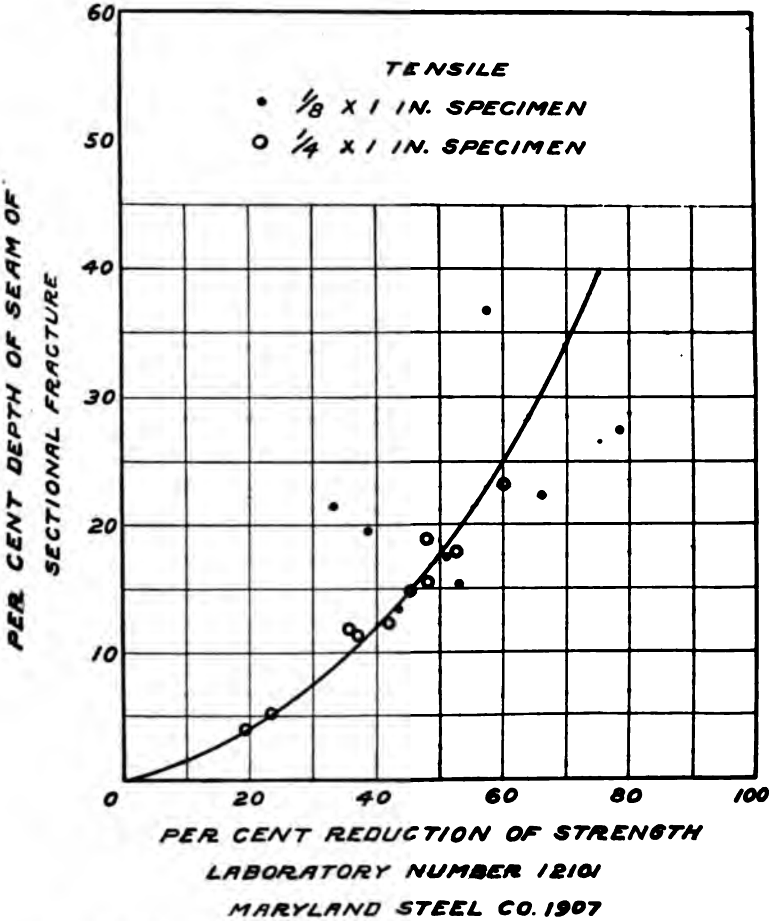


FIG. 17—Percentage decrease in strength with varying depth of seams.

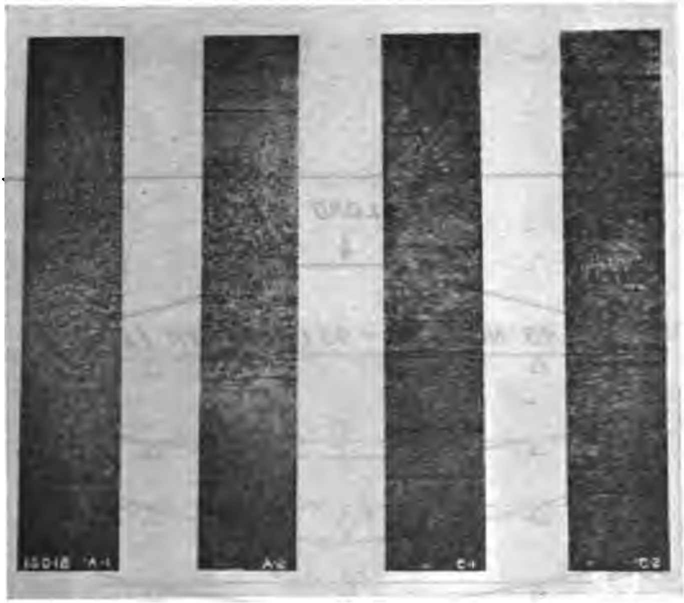


FIG. 18—Specimens from base of rail 15018, etched to bring out seams distinctly. Sections 4 ft. apart in rail base. Section A-1 at end of rail.

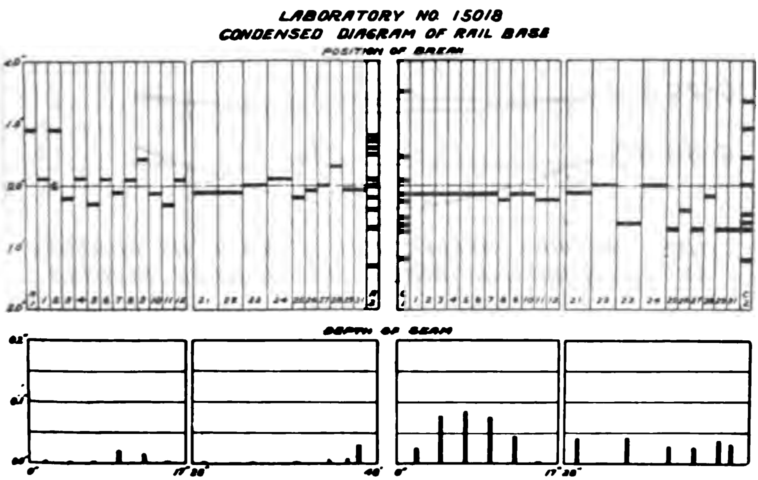


FIG. 19.

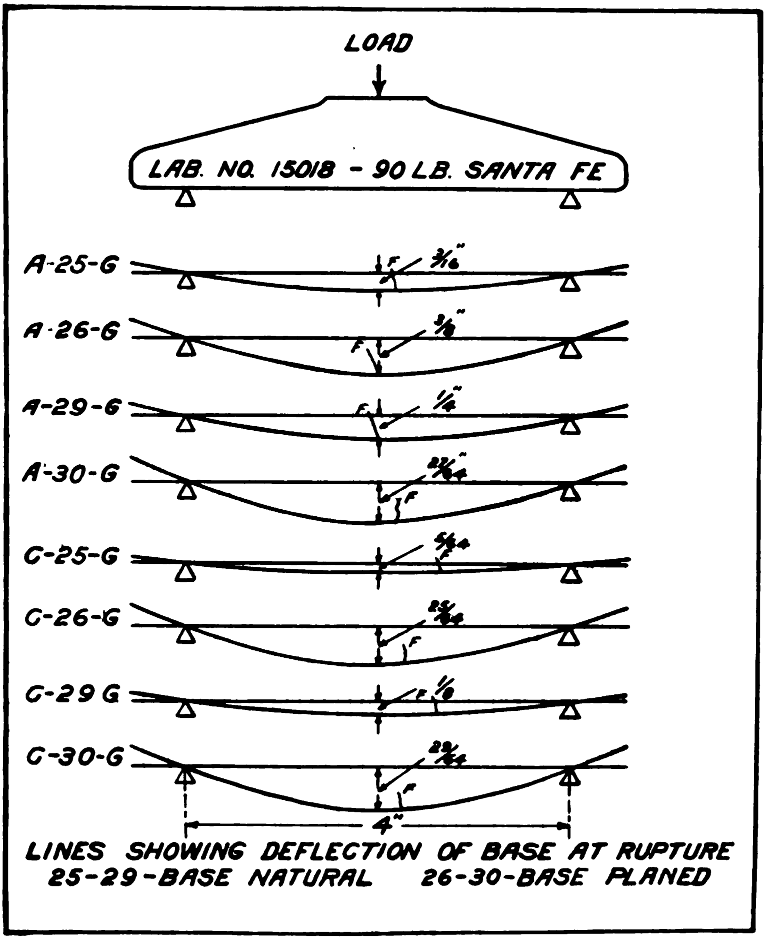

LOAD
LAB. NO. 15018 - 90 LB. SANTA FE
A-25-G
3/16"
A-26-G
3/8"
A-29-G
1/4"
A-30-G
27/64"
C-25-G
5/64
C-26-G
25/64
C-29 G
1/8
C-30-G
29/64
4"
LINES SHOWING DEFLECTION OF BASE AT RUPTURE
25-29-BASE NATURAL 26-30-BASE PLANED

Fig. 20.

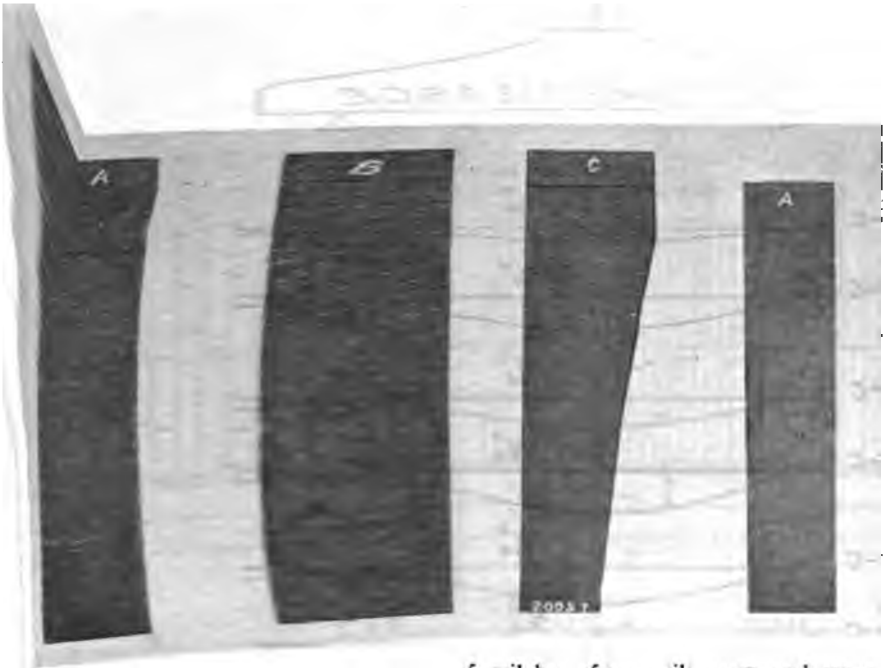


FIG. 21—Sections of rail base from rails 20057 and 17045. 4 ft. apart in base of rail. Section A at end of rail.

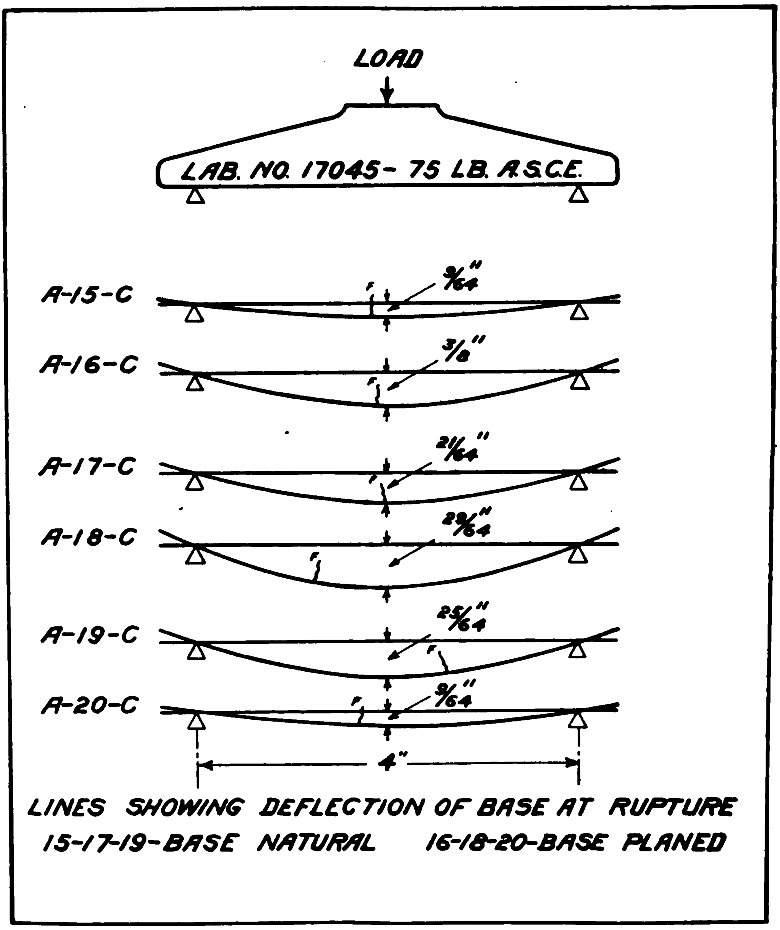

LOAD
LAB. NO. 17045 - 75 LB. A.S.C.E.
A-15-C
9/64"
A-16-C
3/8"
A-17-C
21/64"
A-18-C
29/64"
A-19-C
25/64"
A-20-C
9/64"
4"
LINES SHOWING DEFLECTION OF BASE AT RUPTURE
15-17-19-BASE NATURAL 16-18-20-BASE PLANED

FIG. 22.

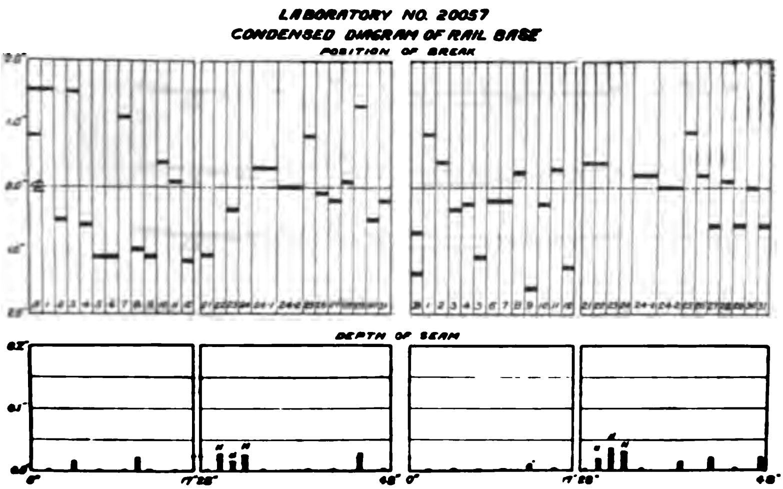

LABORATORY NO. 20057
CONDENSED DIAGRAM OF RAIL BASE
POSITION OF BREAK
DEPTH OF SEAM

FIG. 23.

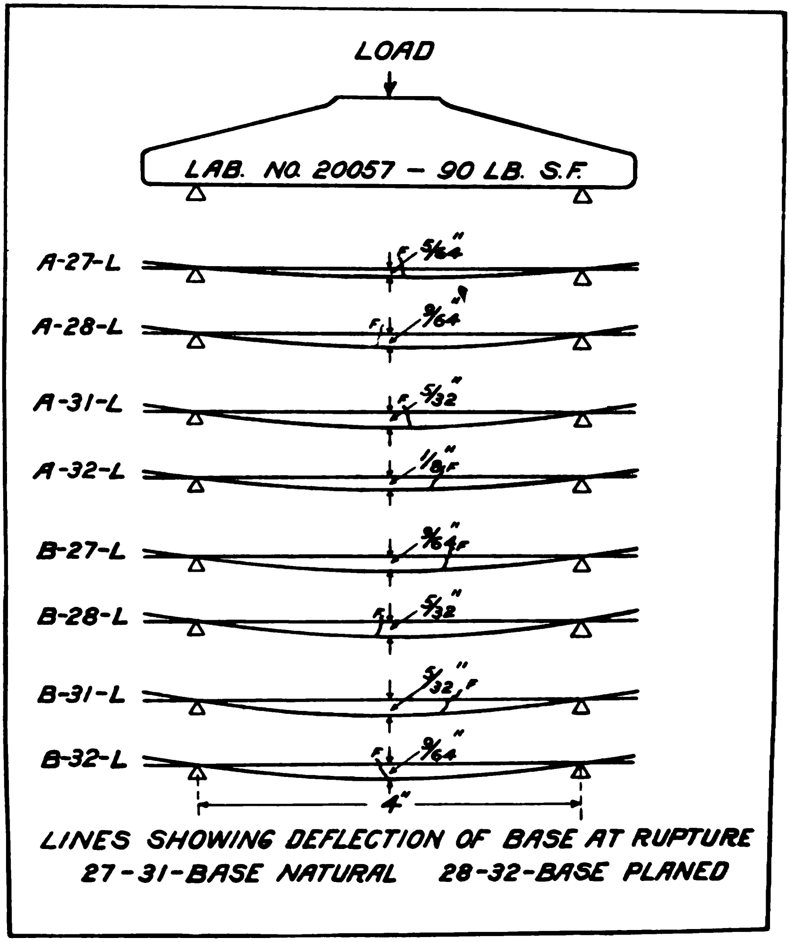

LOAD
LAB. NO. 20057 – 90 LB. S.F.
A-27-L
5/64"
F
A-28-L
9/64"
F
A-31-L
5/32"
F
A-32-L
1/8"
F
B-27-L
9/64"
F
B-28-L
5/32"
F
B-31-L
5/32"
F
B-32-L
9/64"
F
4"
LINES SHOWING DEFLECTION OF BASE AT RUPTURE
27-31-BASE NATURAL 28-32-BASE PLANED

FIG. 24.

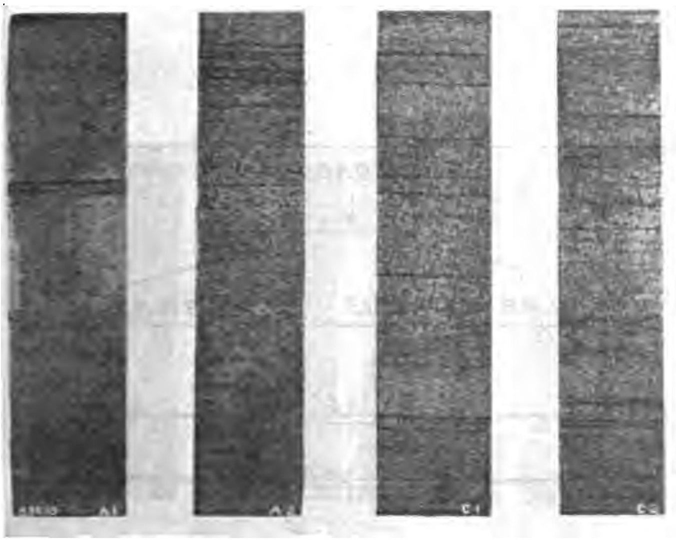


FIG. 25—Showing sections of base of rail 30015. Sections are 4 ft. apart in base of rail. Section A-1 is at end of rail.

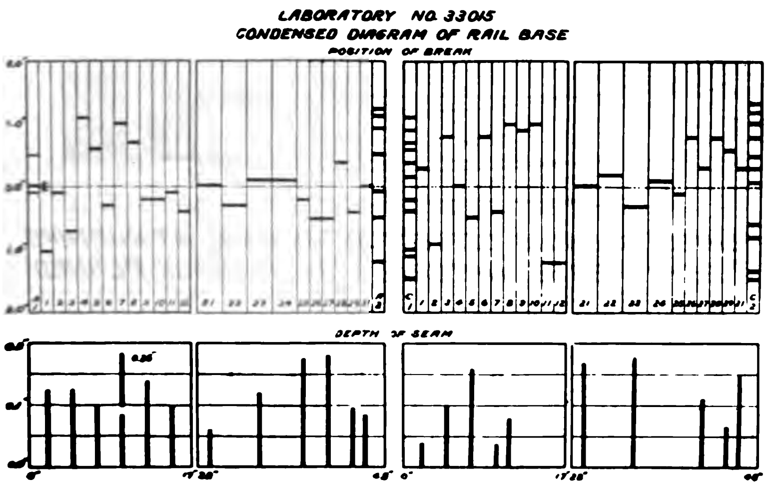
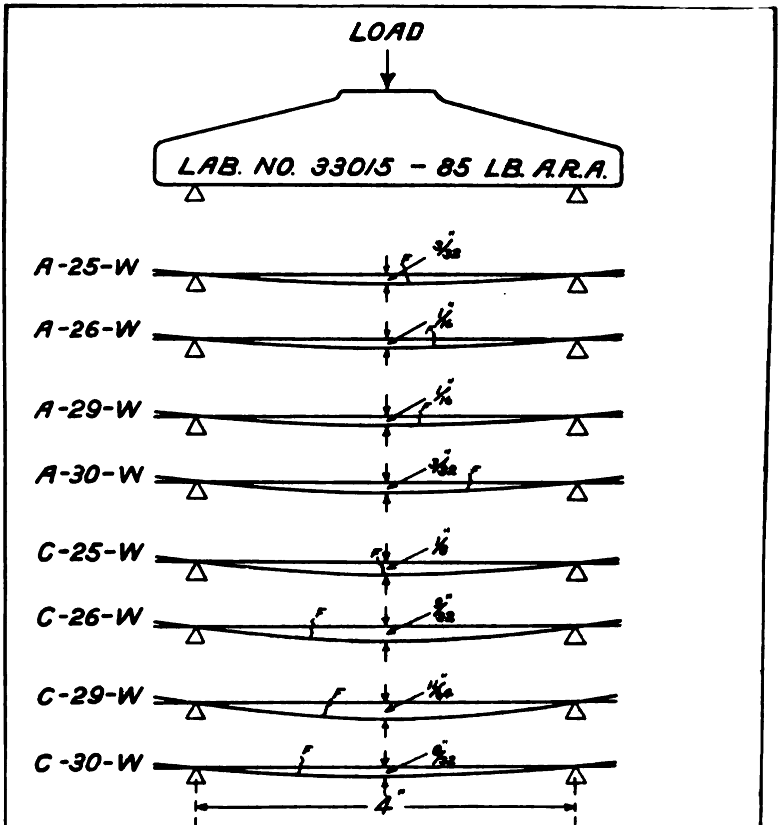


FIG. 26.



LINES SHOWING DEFLECTION OF BASE AT RUPTURE
25-29-BASE NATURAL 26-30-BASE PLANED

Fig. 27.

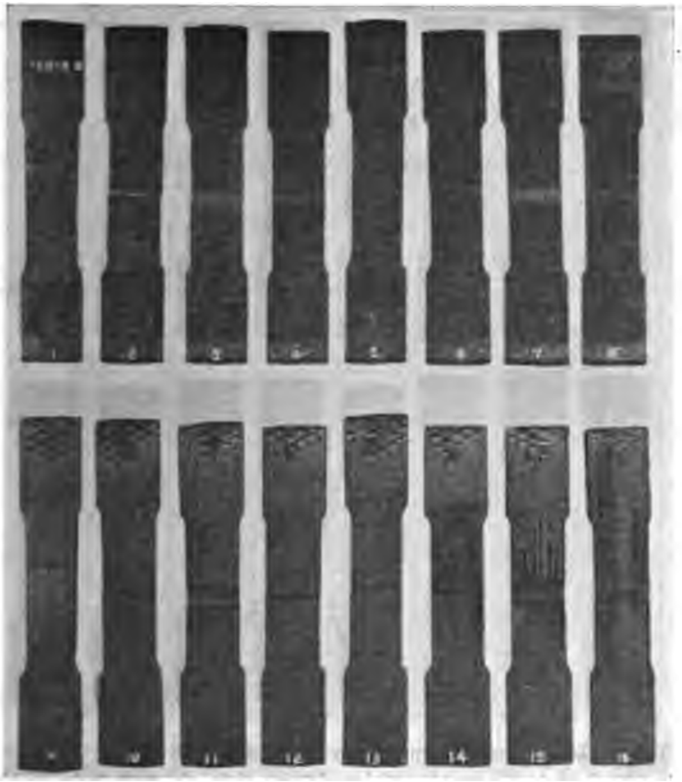


FIG. 28—Tension test specimens B section, rail 15018, after test. Specimens 1 to 8, base in natural condition. Specimens 9 to 16, both surfaces planed. All specimens nicked but 1, 5, 9 and 13. Note the manner failure occurs in nicks.

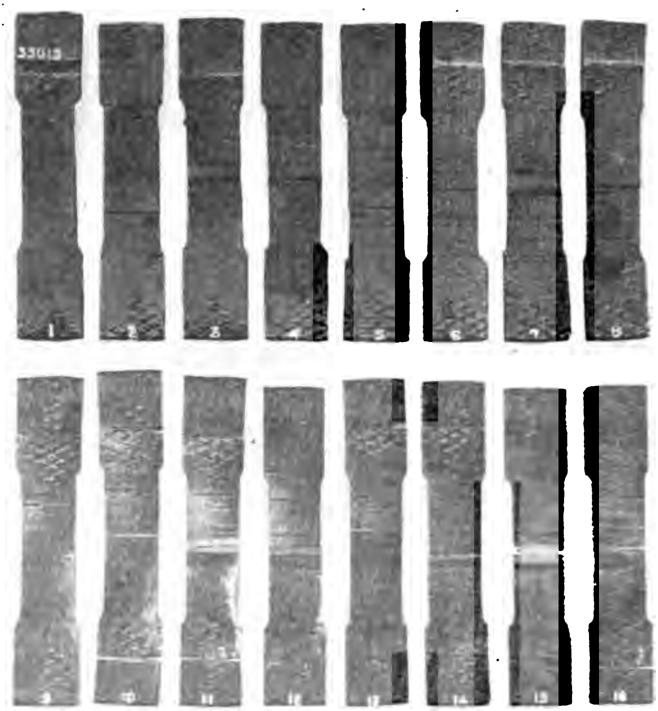


FIG. 29—Tension test specimens B section, rail 33015. Specimens 1 to 8, with both surfaces planed; specimens 9 to 16, with base in natural condition. Specimens 1, 5, 9 and 13 not nicked. Remaining specimens all nicked. Note the few specimens that failed in nicks. Several specimens failed near jaws several times before failing in nick. Irregularity in manner of breaking probably due to segregation.

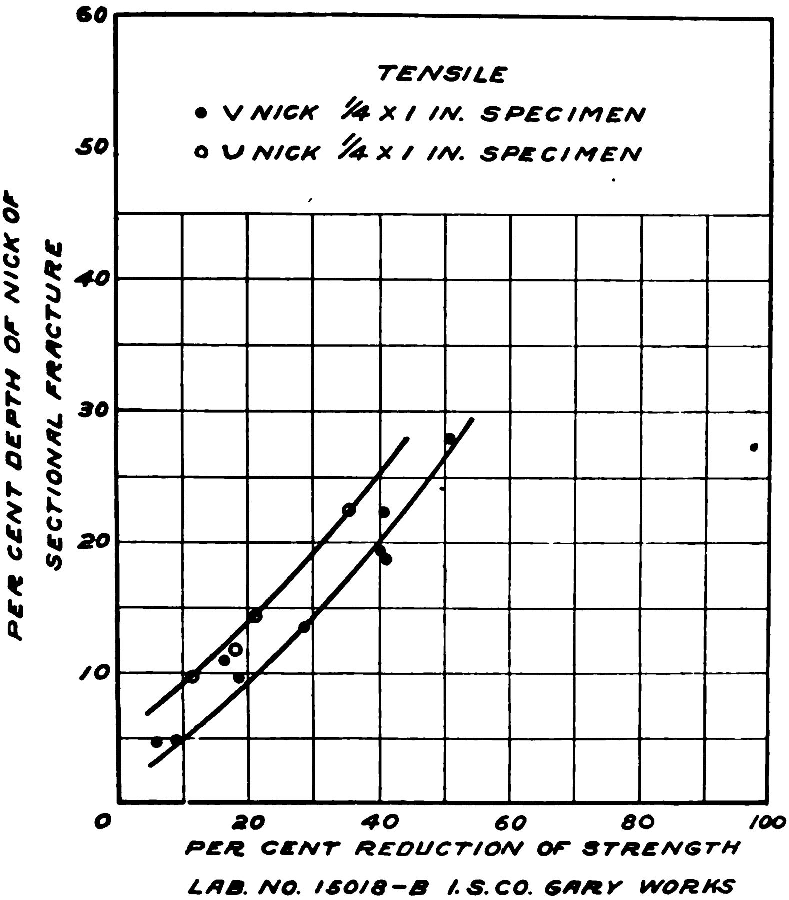

TENSILE
• V NICK 1/4 X 1 IN. SPECIMEN
o U NICK 1/4 X 1 IN. SPECIMEN
PER CENT DEPTH OF NICK OF SECTIONAL FRACTURE
0
10
20
30
40
50
60
0
20
40
60
80
100
PER CENT REDUCTION OF STRENGTH
LAB. NO. 15018-B I. S. CO. GARY WORKS

Fig. 30.

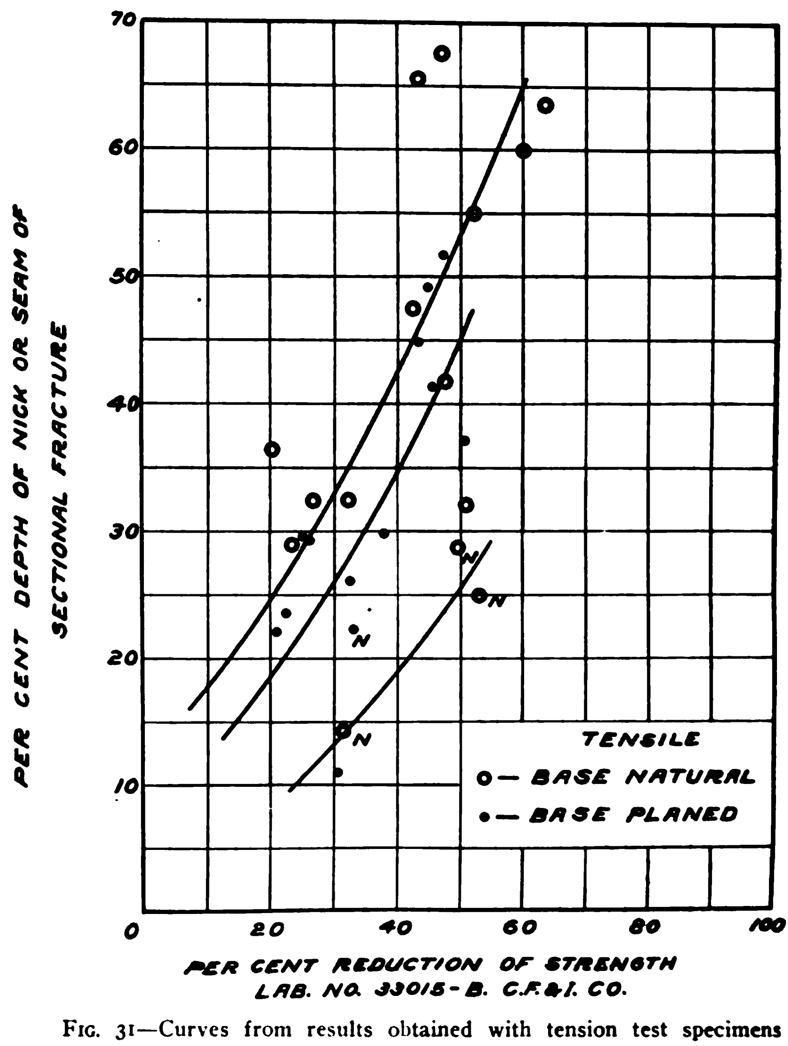


FIG. 31—Curves from results obtained with tension test specimens from B section, rail 33015, showing irregularity in results obtained. Although 12 of the 16 specimens were nicked, only four failed in nicks, the remaining specimens failed in seams. A few specimens failed outside of the reduced sections and were reset for further tests, which accounts for the large number of failures shown for the 16 specimens tested.

FIG. 32—Section of rail base, rail 33015, showing surface in a plane one-quarter of an inch above and parallel to the base. Note the number of dark lines running across the surface in the same direction as the seams existing in the base. These lines have no depth, but are brought out by the effect of the planing tool, indicating an apparent variation in physical structure of metal.

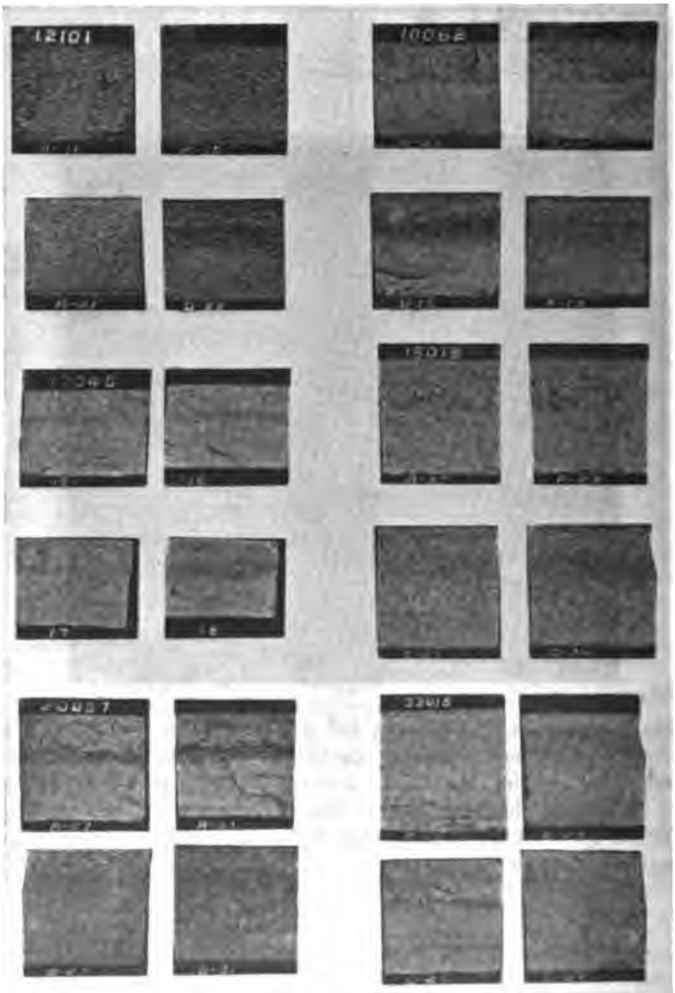


FIG. 33—Fractures of Tensile Specimens.

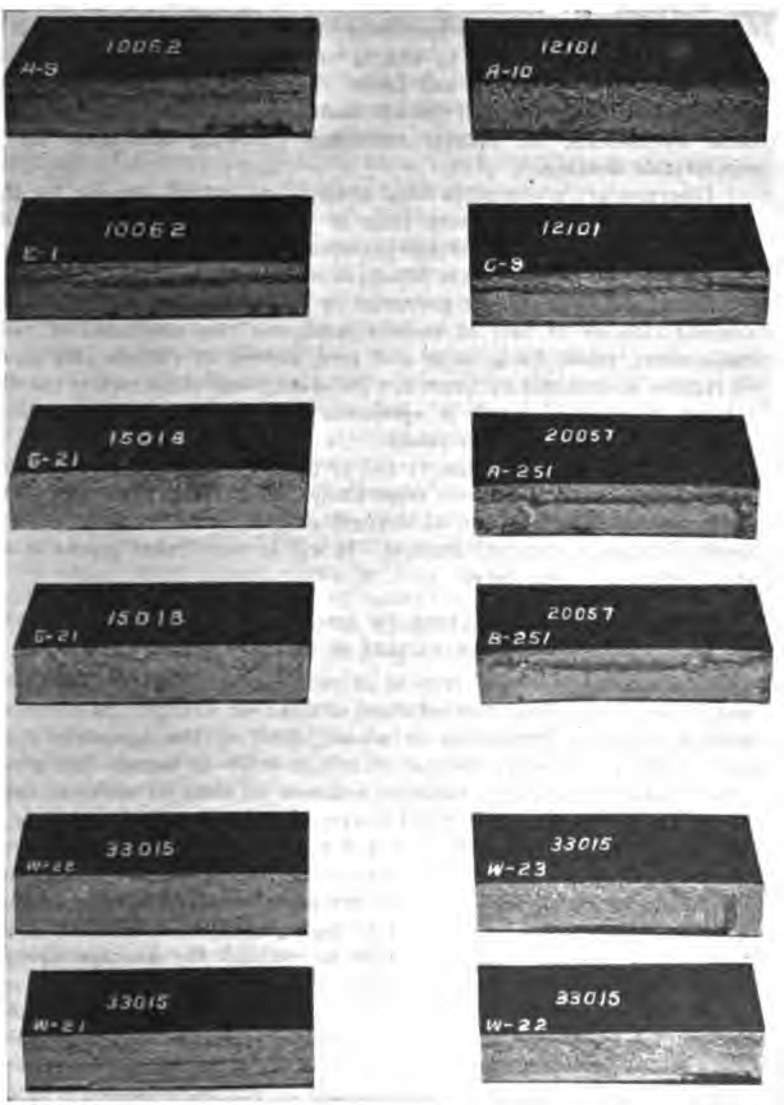


FIG. 34—Fracture of Specimens in Transverse Bend.

yet, the seams become more pronounced in the specimens toward the middle of the rail.

In addition to these six figures, other illustrations are given in Figs. 6, 7 and 8 of the broken test specimens of sections A, B, C, D, E and F of rail 10062, and in Figs. 13 and 14 of the broken test specimens of sections A, B, C and D of rail 12101. The tendency of the specimens to break along certain well-defined seams will readily be noted from these illustrations, the failures sometimes following one seam for a considerable distance.

Diagrams are presented in Figs. 9, 15, 19, 23 and 26, showing for the various transverse and tension tests of the different sections of rails 10062, 12101, 15018, 20057 and 33015, respectively, the position of fracture and the per cent depth of seam, if any, in each specimen.

Additional diagrams are presented in Figs. 10, 16, 20, 22, 24 and 27, showing contour of base of various transverse test specimens of rails 10062, 12101, 15018, 17045, 20057 and 33015 at time of rupture; the point of rupture is indicated by letter E. These diagrams show clearly the decreased ductility of metal in specimens not having the base surface planed to remove the surface seams.

Curves are shown in Figs. 11 and 17 plotted from results of tensions tests of rails 10062 and 12101, respectively. These curves are plotted to show the per cent reduction of strength of metal with varying per cent depth of seam of sectional fracture. It will be noted that results in all cases follow a regular curve.

COMPARATIVE RELATIVE INFLUENCE ON STRENGTH OF METAL OF NICKS AND LAMINATIONS OR SEAMS.

The specimens from *B* sections of rails 15018 and 33015 were nicked and pulled to determine the influence of nicks on strength, as compared with influence of laminations or seams. Four of the specimens from each of these rails were circular nicked in order to secure data which would show comparative weakening influence of nicks of different character. Specimens 2, 3, 4, 6, 7 and 8 were nicked and pulled with base in natural condition and specimens 1 and 5 were pulled with base natural and no nick in order to establish the average true strength of the metal. Specimens 10, 11, 12, 14, 15 and 16 were planed on both surfaces, nicked and then pulled. Specimens 9 and 13 were planed on both surfaces, but were pulled without nicking in order to establish the average strength of the metal with both surfaces planed.

Specimens 1 to 8, inclusive, of *B* section of rail 33015 were planed and all specimens nicked, with exception of specimens 1 and 5, which were pulled in natural condition. Specimens 9 to 16, inclusive, were pulled with base in natural condition and all specimens nicked with exception of 9 and 13.

Figs. 28 and 29 show the tension test specimens from the *B* section of rails 15018 and 33015, respectively, after being tested. It will be noted that the breaks in specimens from rail 15018 occurred in every instance

in the nick, whereas specimens from rail 33015, prepared in an identical manner, broke in an irregular manner, that is, failures did not occur in the nick. The erratic manner in which these specimens failed indicated irregular structure of metal, probably due to segregation.

In Fig. 30 are curves showing effect of nicks on tensile strength of rail. It is at once seen that the curved nick may be much deeper than the "V" nick and still have no greater influence in reducing the tensile strength of the rail. Comparing these results with the curves in Figs. 11 and 17, one notes that the seam has a proportionally greater influence than the nick, and that the curve follows the same general direction.

The irregular results obtained from tension test specimens from rail 33015 may possibly be explained by segregation of the metal; this condition is indicated by Fig. 32 of a section of the rail base from rail 33015, showing surface in a plane one-quarter of an inch above and parallel to the base. A number of dark lines will be noted across this surface, running in the same direction as the seams or laminations existing in the base. These lines have no depth, but are brought out by the effect of the planing tool, indicating an apparent variation in physical structure.

From the variation in results of tests of specimens from rail 33015, as compared with results from other rails, it is apparent that there is a difference in the structure of the metal as well as the character of the seams. From a study of the fractures of the specimens from the various rails under investigation, shown in Figs. 33 and 34, the differences in character of seams may be readily noted.

The figures, however, do not bring out this fact as clearly as revealed in an examination of the original fractures. The seams in the base of rail 33015 are not as clearly defined as the seams in the base of other rails examined, that is, the penetration of the seam is more irregular and it is difficult to determine just at what depth the seam ends, and the metal has a regular molecular bond. The variation in condition and depth of seam is very marked in short linear distances of rail.

DATA.

Inasmuch as this is a detailed study of rail bases containing seams or laminations, all representative test data from one rail have been introduced in order that a detailed check of results obtained might be made and opportunity afforded for checking up conclusions made as a result of this investigation.

Information is shown relative to tension tests giving computed values of elastic limit and ultimate strength in pounds per square inch of the material, together with the per cent elongation in 2 in. and per cent reduction of area. Data are also presented showing, when the fracture occurred at seam, the depth of the seam and per cent depth of the seam based on the depth of the section.

Information is shown relative to transverse tests giving actual size at the center of the specimens tested, the total force necessary to frac-

ture specimen, and the ultimate strength of the specimen in pounds per inch. Computations are also given, strictly for comparative purposes, of the estimated strength in pounds per inch of material for a standard height of either 0.4 in. or 0.8 in. The depth of the seam in inches, as well as the per cent of fractured area showing seams, is also given.

TABLE 5—TENSION TEST, LABORATORY NO. 10062. SIZE OF SPECIMEN, 1 X 1/8 IN

Specimen	Pounds per sq. in. Elastic Limit	Pounds per sq. in. Ultimate Strength	Per cent of Elongation	Per cent of Reduction	Depth of Seam Inches	Depth of Seam Per cent	Fracture from Top Edge Inches
A-1-1	59,200	59,200	1.0	0.0	0.005	3.6	2 70
2	57,800	99,600	4.5	2.1	....	...	2.55
3	51,200	70,900	1.0	0.6	0.006	4.4	2.75
4	64,800	106,600	4.5	0.5	....	...	2.95
B-1-1	65,800	84,000	3.0	1.0	0.008	6.1	2.90
2	76,600	95,800	3.0	3.9	....	...	1.50
3	57,000	61,100	2.0	0.3	0.028	21.1	2.95
4	73,400	91,400	3.0	1.2	....	...	2.15
C-1-1	64,900	64,900	2.0	0.0	0.012	9.2	2.55
2	74,000	108,600	4.5	3.4	....	...	3.90
3	59,400	75,300	2.0	0.3	0.010	7.5	2.55
4	65,000	107,000	4.0	1.0	....	...	1.50
D-1-1	71,100	85,600	2.0	4.0	0.010	7.3	2.65
2	69,600	91,400	3.0	3.8	....	...	1.50
3	70,700	84,900	2.0	0.7	0.010	7 7	2.65
4	64,600	102,000	4.5	2.9	....	...	2.55
E-1-1	43,900	43,900	1.5	0.0	0.020	14.9	2.90
2	58,300	100,500	4.5	4.1	....	...	2.55
3	51,200	67,200	2.0	1.2	0.004	3.1	2.44
4	58,700	90,000	3.5	2.3	....	...	2.35
F-1-1	35,000	35,000	1.0	0.0	0.050	35.5	2.20
2	43,500	108,500	6.5	3.6	....	...	2.50
3	28,600	28,600	1.5	0.0	0.047	32.6	2.35
4	71,300	98,900	3.5	3.0	....	...	3 25

TABLE 6—TENSION TEST, LABORATORY NO. 10062. SIZE OF SPECIMEN, 1 X ¼ IN.

Specimen	Pounds per sq. in. Elastic Limit	Ultimate Strength	Per cent of Elongation	Reduction	Depth of Seam Inches	Per cent	Fracture from Top Edge Inches
A-5-I	55,800	76,400	2.5	2.3	0.030	11.9	2.80
6	67,800	97,000	4.0	2.8	....	...	2.75
7	49,000	49,000	1.5	0.3	0.039	15.6	1.90
8	63,600	105,000	5.0	4.1	....	...	2.55
B-5-I	61,800	69,800	2.0	0.7	0.031	12.5	2.15
6	47,000	99,800	4.0	2.4	....	...	2.95
7	59,100	69,200	2.5	0.4	0.026	10.5	2.15
8	50,800	112,500	6.5	5.9	....	...	2.30
C-5-I	60,200	86,100	3.0	2.6	0.008	3.2	3.00
6	62,000	106,600	5.5	4.7	....	...	3.00
7	63,000	93,800	4.0	3.0	0.005	2.0	3.00
8	62,800	108,500	6.5	5.1	....	...	2.70
D-5-I	65,300	85,800	2.5	2.3	0.011	4.4	2.65
6	58,800	104,000	5.0	3.8	....	...	2.40
7	59,600	72,400	2.5	1.3	0.012	4.7	2.60
8	52,200	109,500	6.5	5.6	....	...	2.30
E-5-I	54,400	82,900	3.0	1.7	0.018	7.5	2.45
6	47,200	103,700	5.5	3.6	....	...	2.70
7	53,000	58,500	2.0	0.7	0.022	9.0	2.95
8	53,500	91,400	3.5	1.4	....	...	2.60
F-5-I	53,200	60,200	2.0	0.0	0.027	11.1	2.30
6	60,500	107,500	5.0	4.7	....	...	2.65
7	45,500	61,100	2.0	0.0	0.031	12.5	2.30
8	52,500	87,800	4.0	1.5	....	...	2.35

TABLE 7—TRANSVERSE TEST, LABORATORY NOS. 12101 AND 10062. SIZE OF SPECIMEN, 2 X 0.4 IN.

Laboratory No. 12101 Specimen	Size, Inches	Height Squared Inches	Ultimate Strength Pounds	Ultimate Strength Lbs. per in.	Strength Per inch H-O 4 in.	Reduction of Strength Per cent	Depth of Seam Inches	Depth of Seam Per cent	Fracture from Top Edge, in.
A-9-I	2.02 x 0.416	0.1730	6,020	2,980	2,760	33.0	0.052	12.5	2.77
10	2.02 x 0.414	0.1715	9,600	4,750	4,430				2.33
B-9-I	2.01 x 0.427	0.1824	8,910	4,430	3,890	5.6	0.010	2.3	2.57
10	2.01 x 0.425	0.1806	8,820	4,390	3,890				2.76
C-9-I	2.01 x 0.406	0.1650	7,850	3,910	3,790	8.0	0.010	2.5	2.49
10	2.01 x 0.407	0.1658	8,790	4,380	4,230				2.70
D-9-I	2.01 x 0.405	0.1640	6,460	3,220	3,140	23.8	0.036	8.9	2.58
10	2.01 x 0.411	0.1690	9,260	4,610	4,360				2.57
E-9-I	2.01 x 0.430	0.1850	8,370	4,170	3,610	12.4	0.020	4.7	2.97
10	2.01 x 0.428	0.1830	8,190	4,080	3,570				2.68
F-9-I	2.01 x 0.410	0.1682	6,040	3,010	2,850	30.8	0.026	6.4	2.32
10	2.01 x 0.407	0.1657	8,750	4,360	4,210				2.44

TABLE 8—TRANSVERSE TEST, LABORATORY NO. 10062.

Specimen	Size, Inches	Height Squared Inches	Initial Load Pounds	Temperature Degrees F.	Ultimate Pounds	Strength Lbs. per Inch	Strength Per inch H-O. 8 Inch Pounds	Depth of Inches	Seam Per cent	Fracture from Top Edge Inches
A-11-I	1.033 x 0.778	0.605		Room-90	11,040	10,690	11,300	0.056	7.2	2.84
13	1.034 x 0.782	0.612		20	16,920	16,350	17,100	.....	...	2.83
15	1.020 x 0.782	0.612	7,000 10 blows		18,120	17,760	18,570	.....	...	2.85
B-11-I	1.013 x 0.815	0.665		20	15,540	15,350	14,780	.....	...	1.60
13	1.028 x 0.811	0.658		Room-90	15,440	15,020	14,610	0.027	3.3	1.60
15	1.030 x 0.810	0.656	10,000 10 blows		17,520	17,000	16,600	0.022	2.7	1.55
C-11-I	1.045 x 0.808	0.653		Room-90	17,100	16,360	16,050	0.020	2.5	2.64
13	1.039 x 0.805	0.648		20	19,800	19,050	18,820	.....	...	2.54
15	1.045 x 0.800	0.640	10,000 5 blows		10,000	9,560	9,560	.....	...	2.58
D-11-I	1.000 x 0.820	0.672		[illegible]	[illegible]	15,690	14,950	.....	...	2.80
13	1.021 x 0.820	0.672		Room-90	19,210	18,820	17,920	.....	...	2.80
15	1.038 x 0.809	0.655	10,000 10 blows		19,600	18,900	18,470	.....	...	2.40
E-11-I	1.031 x 0.821	0.675		Room-90	14,580	14,140	13,830	0.023	2.8	2.40
13	1.038 x 0.823	0.677		20	15,150	14,600	13,800	0.017	2.0	2.20
15	1.037 x 0.820	0.672	10,000 10 blows		15,100	14,560	13,860	0.017	2.0	2.40
F-11-I	1.002 x 0.800	0.640			[illegible]	11,350	11,350	0.040	5.0	2.40
13	1.021 x 0.800	0.640		Room-90	10,490	10,270	10,270	0.054	6.8	2.35
15	1.050 x 0.798	0.638	8,000 1 blow		8,000	7,620	7,640	0.053	6.7	2.35

TABLE 9—TRANSVERSE TEST, LABORATORY NO. 10062.

Specimen	Size, Inches	Height Squared Inches		Temp. Degrees F.	Specimen in Lbs. Elastic Limit	Specimen in Lbs. Ultimate Strength	Ultimate Strength Lbs. Per Inch	Strength Per Inch Specimen 1 in.x0.8 in. Pounds	Depth of Inches	Seam Per cent	Fracture from Top Edge Inches
A-17-I	1.013 x 0.735	0.541	B P	82	11,000	19,700	19,450	23,000	..	..	3.00
19	1.021 x 0.741	0.549	B P	12	11,000	20,000	19,580	22,800			3.00
21	1.022 x 0.790	0.625	B N	82	12,000	17,900	17,520	17,950			2.55
B-17 I	1 014 x 0.739	0.546	B P	82	11,000	19,920	19,650	23,000	..	..	2.95
19	0.992 x 0.737	0.543	B P	12	12,000	19,140	19,300	22,780			2.80
21	0 962 x 0.802	0.644	B N	82	12,000	16,620	17,280	17,180			2.30
C 17-I	0 975 x 0.730	0.533	B P	80	10,500	17,500	17,950	21,550	..	..	2.50
19	0.952 x 0.729	0.532	B P	10	10,500	16,920	17,760	21,290			2.40
21	0.867 x 0.742	0.551	B P	82	10,000	17,000	19,610	22,800			2.50
23	0.794 x 0.742	0.551	B P	12	9,000	16,000	20,150	23,400			2.50
D-17-I	1.006 x 0.731	0.535	B P	80	10,500	16,780	16,680	19,950	..	.	2.50
19	1.015 x 0.743	0.552	B P	10	11,500	18,610	18,340	21,260			2.75
21	1.003 x 0.740	0.548	B P	82	11,000	18,270	18,220	21,300			2.65
23	0.900 x 0.748	0.560	B P	12	10,000	17,080	18,980	21,700			2.50
E-17-I	1.025 x 0.734	0.539	B P	80	11,000	16,400	16,000	19,000	..	..	2 25
19	1.015 x 0.730	0.533	B P	10	12,000	13,300	13,100	15,740			2 25
21	1.024 x 0.739	0.546	B P	82	11,000	13,600	13,290	15,580			2 25
23	1.015 x 0.735	0.540	B P	12	11,000	11,000	10,840	12,850			2.35

Note: B P--Base Planed.
B N Base Natural

TABLE 10—AVERAGE RESULTS OF TENSION TEST.

	Laboratory Number.											
	10062 Natural	Base Planed	12101 Natural	Base Planed	15018 Natural	Base Planed	17045 Natural	Base Planed	20057 Natural	Base Planed	33015 Natural	Base Planed
Spec. 1 & 2, ⅛-in. Crosswise												
Ult. Str., lbs. per sq. in.	63,400	100,000	53,500	112,190	80,950	118,850	100,900	94,800	88,970	98,000	51,820	70,820
Elong. in 2-in., per cent.	1.75	4.1	1.5	7.0	3.6	6.6	4.3	2.5	3.2	2.9	1.2	3.0
Depth of Seam, per cent.	12.7	..	21.9	...	19.4	...	...	..	3.1	...	78.0	23.6
Spec. 3 & 4, ¼-in. Crosswise												
Ult. Str., lbs. per sq. in.	72,100	102,770	61,010	113,130	77,350	114,100	100,000	97,450	96,800	95,270	65,000	62,150
Elong. in 2-in., per cent.	2.45	5.1	1.8	8.6	2.9	6.4	3.3	2.8	3.1	2.9	2.6	2.
Depth of Seam, per cent.	8.8	...	15.8	...	17.4	...	...	..	...	1.7	54.8	25.0
Spec. 5 & 6, ⅜-in. Crosswise												
Ult. Str., lbs. per sq. in.					106,050	120,850	101,350	106,400	96,970	102,350	60,450	67,550
Elong. in 2-in., per cent.					4.8	8.1	4.0	4.5	3.2	3.6	1.4	1.8
Depth of Seam, per cent.					4.1	...	...	...	0.8	...	16.2	20.0
Spec. 7 & 8, ⅛-in. Longitudinal												
Ult. Str., lbs. per sq. in.					117,750	122,190	114,600	118,200	113,100	115,750	96,200	90,000
Elong. in 2-in., per cent.					8.5	6.1	7.0	7.0	14.4	12.6	11.4	13
Depth of Seam, per cent.					...	...	...	...	....	....	....	..
Spec. 9 & 10, ¼-in. Longitudinal												
Ult. Str., lbs. per sq. in.					122,550	126,220	121,700	125,800	116,670	117,470	95,650	96,330
Elong. in 2-in., per cent.					13.6	14.9	18.0	18.0	17.0	16.3	21.6	16.9
Depth of Seam, per cent.					....	....	....	...	....	....	....	....

TABLE II—AVERAGE RESULTS OF TRANSVERSE TESTS.

Laboratory Number	Specimen Approximately 2 x 0.4 Inches — Base Natural: Ultimate* Strength Linear Inch, Pounds	Depth of Seam Per cent	Number of Values in Average	Base Planed: Ultimate* Strength Linear Inch, Pounds	Depth of Seam Per cent	Number of Values in Average	Specimen Approximately 1 x 0.9 Inches — Base Natural: Ultimate** Strength Linear Inch, Pounds	Depth of Seam Per cent	Number of Values in Average	Base Planed: Ultimate** Strength Linear Inch, Pounds	Depth of Seam Per cent	Number of Values in Average	***Specimen
10062	3,360	6.2	6	4,100		6	15,400	1.9	18	21,000		15	
12101	3,465	10 3	5	4,360		3	13,800	4.6	20	18,020		20	
15018	4,900	5.1	4	5,430		4	19,700	1.9	8	24,550		6	
17045	....	...	.	......		.	22,300	0.0	3	20,230		3	
20057	5,340	0.0	2	4,150		2	20,240	1.2	8	20,100		8	
33015	3,355	22.5	4	3,730	36.6	4	15,990	11.6	8	15,260	14.2	6	
	Calculated Strength per Linear Inch—Full Base of Rail												***Specimen
10062	16,675	2.8		20,350			19,130	1.7		26,000			1.0 x 0.89
12101	17,200	4.5		21,630			17,120	4.1		22,350			1.0 x 0.89
15018	30,600	2.0		33,900			30,800	1.5		38,350			1.0 x 1.00
17045	......	...		......			24,850	...		22,550			1.0 x 0.84
20057	33,400	...		25,940			31,620	1.0		31,400			1.0 x 1.00
33015	20,950	9.0		23,300	14.6		24,950	9.3		23,850	11.4		1.0 x 1.00

NOTE: *Ultimate Strength as Beam, Center Loaded**

*B—1.0 inch **B—1.0 inch
H—0.4 inch H—0.8 inch
L—4.0 inch L—4.0 inch

***Size of Specimen in Inches

Distance between supports, 4 inches.

DISCUSSION.

Extent and Number of Seams: The investigation shows that there may be numerous seams in the lower part of the rail base. Photographs of etched rail bases to illustrate this are reproduced in Fig. 5 for an 85-lb. ASCE section, rolled by the Illinois Steel Company, South Works; in Fig. 12 for an 85-lb. ASCE section, rolled by the Maryland Steel Company; in Fig. 18 for a 90-lb. Santa Fe section, rolled by the Illinois Steel Company, Gary Works; in Fig. 21 for a 75-lb. ASCE section, rolled by the Colorado Fuel and Iron Company; in Fig. 21 for a 90-lb. Santa Fe section, rolled by the Lackawanna Steel Company, and in Fig. 25 for an 85-lb. ARA section, rolled by the Colorado Fuel and Iron Company.

The sections for etching were taken either 2 or 4 feet apart from one end of the rail and show that any particular seam may not extend from end to end of a rail. Moreover, there may be more seams in one portion of a rail than in another. Of the rails investigated, laboratory No. 17045, from the Colorado Fuel and Iron Company showed the least number of seams. In as much as this rail failed on account of derailment and not with characteristic rail failure due to seams in base, it may be only logical that such condition should exist.

Data and figures show that the absence of seams from the whole rail cannot be assured on the grounds that any one section does not show seams. The uncertainty in location and continuation of a seam in rail base is in keeping with the depth of the seam.

The actual depth of seam was determined only in cases of fracture, consequently, unless the fracture was in the same seam for sections tested, the variation in depth of any one seam could not be established. Data on depth of seams are shown in various data sheets and figures. The extent and depth of seams is also well shown for rail number 10062 by photographs and diagrams in Figs. 6 to 9, inclusive.

The diagram in Fig. 9 shows developed seams for a half inch on either side of center line of base of rail. The heavy lines on sections A, B, C, etc., are seams shown by etching tests. The heavy lines on numbered sections show position of fracture of test piece, the vertical lines on scale below represent depth of seam, if any, in fractured test piece. Similar diagrams for other rails are found in Figs. 15, 19, 23 and 26.

No attempt was made to investigate thoroughly the seams near the outer edges of bases, as experience has shown that these seams are of less influence on failure of rails than seams near the center of lower surface of rail base. A study of fractures shows that where failure continues along the same seam for sections covering a distance of 12 in., the seam may vary in depth from 0.02 to 0.10 in. Fractures may occur in one seam and on next test in another seam. The line of fracture from tension test may continue with transverse test specimens. The structural appearance of the seam is the same whether specimen is broken under transverse or tension test.

Seams and Tensile Properties. The object of this investigation was to study conditions, not the production of conditions. No attempt is made to explain the nature of a seam or to investigate the cause of seams, their existence is established, their deteriorating influence is recognized, and it is further recognized that seams must be eliminated from rail bases or their influence neutralized.

The presence of seams in metal reduces the tensile strength as well as the ductility of the metal. The seam or lamination produces a state of discontinuity, the metal indicating a peculiar segregation of impurities from the steel and a consequent breaking down in the co-efficient for the transfer of molecular stress.

The study of some 500 tests in detail leads to the deduction that seams in rail bases decrease the strength and ductility of the rail base in cross-wise direction. These facts are shown graphically. In Figs. 11 and 17 the decrease in tensile strength due to seams is seen to vary from 15 to 70 per cent. of the strength of adjacent material containing no seams. With only 10 per cent of seam in a small tension test specimen, the decrease in ultimate strength is almost 40 per cent.

The decrease in ductility for transverse tests is shown graphically in Figs. 10, 16, 20, 22, 24 and 27. The decrease is most pronounced in Fig. 20, and least prominent in Fig. 24. The two rails in question are both 90-lb. Santa Fe section.

The individual average results of all tension tests of rails investigated are presented graphically in Fig. 35 in order, if possible, to bring out the relation between ductility, tensile strength and depth of seam in a conclusive way. The per cent of seam of fractured test piece is shown by heavy black horizontal lines on the right. The tensile strength is shown by double ruled lines. The per cent elongation is shown by heavy black lines superimposed on ultimate strength lines.

Detailed study of different tests and for different rails may lead to different conclusions. No conclusions from rail number 33014 showing relations can be made general, because this rail upon final investigation was found to have, not only pronounced seams in the lower base surface, but laminations throughout the head, base and web. In general, the ductility is greatly decreased by presence of seams.

The presence of a seam is not easily determined. The seams were assumed to be gone after the base was planed down, unless the fracture showed seam. Planing down the surface, however, is not conclusive assurance that homogeneity in structure is attained. This point is most pronouncedly brought out by Fig. 32. It does not need an etching solution to show discontinuity in structure of this rail, even a quarter of an inch above the base surface. The varying hardness of the metal is clearly indicated by the play of light and shade on the planed surface.

The average results show a further decrease in strength and ductility for transverse tests made at comparatively low temperatures. There was a similar tendency when the specimen is subjected to a blow or a number of blows under initial load. For the latter test only a light blow was

struck—a 7½-lb. bar falling through a distance of 2 ft. The results obtained are not sufficient to warrant definite conclusions, although they indicate a tendency.

A comparison of tensile properties for specimens with seams as against specimens with nicked or tool marked surfaces has been made a side line of investigation with results shown graphically in Fig. 31.

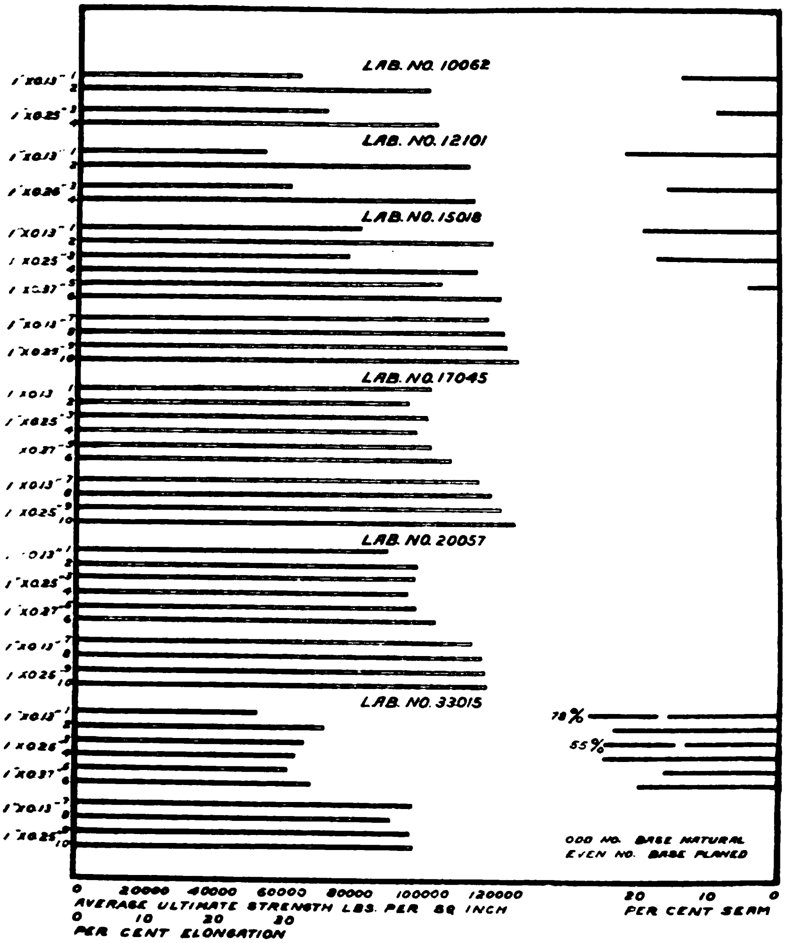


FIG. 35—Average Results of Tension Tests.

Transverse and Longitudinal Structure. There is some considerable variation in tensile properties, as shown in tabulated data, which should require explanation. To get a basis for comparative results, tests were made on specimens taken longitudinal with rail base, tests were also made

to determine the influence of surface metal. As a general rule the ⅛-in. test pieces show less elongation than the ¼-in. specimens. From results of tests on longitudinal specimens it is assumed that surface metal has no decidedly unfavorable influence on tensile properties.

An interesting feature was the study of tensile properties of rail 15018, with the average elongation increasing from 6 to 14 per cent. in a distance of 18 in. along the rail and then falling, within a distance of 36 in. to 1 per cent.; the average ultimate strengths corresponding were 112,000, 123,000 and 42,000 lbs., respectively. The maximum strength and ductility were again manifest 48 in. beyond the first maximum, indicating a periodical rise and fall in physical structure in crosswise direction with advance along the rail. The rail in question was an open-hearth 90-lb. rail. This rise and fall of tensile properties is also shown in rails 17045, 33015, and to some extent in rail 20057, although in the latter rail the variation is more in tensile strength than ductility.

The relation between the tensile properties crosswise and lengthwise of base of rail was obtained for four of the six rails investigated. The data of tabulated average results are of unusual interest, as shown in Tables 10 and 11.

The average results for crosswise tests show a decided decrease in tensile strength and elongation due to base having seams therein. Individual cases show even more pronounced variation. The tests made along the rail give average results with a decided increase in tensile strength and elongation. In the average results there are rails included with such peculiar characteristics that average tensile properties are shown in Table 11 for individual rails.

TABLE 12—AVERAGE RESULTS OF TENSION TESTS ALL RAILS.

Thickness of Specimen Inches.	Condition of Base.	Tensile Strength Pounds Per sq. in.	Elongation Per cent. in 2 in.	Per cent. Tensile Strength.	Decrease. Elongation.
		CROSSWISE OF BASE.			
⅛	Planed	99,110	4.4	..	..
⅛	Natural	73,240	2.6	26	41
¼	Planed	97,480	4.3	..	..
¼	Natural	78,710	2.6	19	43
⅜	Planed	99,290	4.5	..	..
⅜	Natural	91,200	3.3	8	27
Average	Planed	98,550	4.6	..	..
	Natural	79,730	2.8	20	40
		LENGTHWISE OF BASE.			
⅛	Planed	111,540	9.8		
⅛	Natural	110,410	10.4		
¼	Planed	116,450	16.5		
¼	Natural	114,150	17.5		
Average	Planed	114,000	13.2		
	Natural	112,280	14.0		

TABLE 13—AVERAGE RESULTS TENSION TESTS INDIVIDUAL RAILS.

Rail No.	Condition of Base.	Tensile Strength Pounds Per sq. in.	Elongation Per cent. in 2 in.	Per cent. Tensile Strength.	Decrease. Elongation.
		SPECIMENS TAKEN CROSSWISE OF RAILS.			
10062	Planed	101,390	4.6	..	..
	Natural	67,750	2.1	33	55
12101	Planed	112,660	7.8	..	..
	Natural	57,250	1.8	49	77
15018	Planed	117,930	7.0	..	..
	Natural	88,120	3.8	26	46
17045	Planed	99,550	3.3	1	15
	Natural	100,720	3.9	..	..
20057	Planed	98,540	3.4	..	..
	Natural	94,250	3.2	4	6
33015	Planed	66,840	3.3	..	..
	Natural	59,090	1.7	12	49
Average	Planed	98,550	4.6	..	..
	Natural	79,730	2.8	20	40
		SPECIMENS TAKEN LENGTHWISE OF RAILS.			
15018	Planed	124,200	11.5	..	..
	Natural	120,150	11.1	3	4
17045	Planed	122,000	12.5	..	..
	Natural	118,050	12.5	3	..
20057	Planed	116,610	14.5	..	8
	Natural	114,890	15.7	2	..
33015	Planed	93,170	15.2	3	8
	Natural	95,930	16.5	..	..
Average	Planed	114,000	13.2	..	6
	Natural	112,280	14.0	2	..

In comparison of decreased strength for the ⅛ and ¼ in. tension test specimens, the average results are nearly the same, indicating a permanent decrease in tensile properties due to seams in the base. In comparing these results with the ⅜-in. tension specimens, however, it is seen that the thicker specimens show up with less decrease in tensile strength and elongation.

Consideration, however, must be given to rail 33015, which entered into average results, as this rail was a most peculiar rail in its structure having laminations in the interior, as well as on the surface of the base. The elimination of results of tests on this rail for average results shows that the per cent of seams was practically the same for the ¼-in. and ⅛-in. specimens, and very much smaller for the ⅜-in. specimens, so that results are conclusive that the decreased strength is due to the per cent of seams in the base of the rails.

For specimens lengthwise of the base it cannot be expected that a small test specimen would represent fully the character of the base, as it might or might not contain a representative portion of seams. For normal conditions, however, the variation in strength or ductility may favor the base of rail being planed or the base of the rail being natural.

An analysis of stresses in the base of a rail shows a peculiar change in conditions with longitudinal stresses at one point and direct compressive stresses at another, with varying kinds of stresses for intermediate points. The result is that the lines of stress existing in the base of a rail may take any direction. The effect of the seams is that of introducing surfaces of discontinuity in the metal with the result that the lines of stress exerted on adjacent molecules are turned from normal direction. There is a consequent concentration of stresses along the edges of the seam which result in a fracture.

Where seams lie parallel with the line of stress their effect in producing highly concentrated stresses is less than where they lie perpendicular to the line of stress, consequently specimens taken crosswise of the rail should show considerably greater decrease in strength and ductility than specimens taken lengthwise.

Study of Different Rail Bases. An investigation of this kind naturally brings up the question as to the relative strength of the different rail bases. This is of particular importance at the present time when there is such a tendency to increase the base, or, if not, a tendency to increase the fillet at the bottom of the web, thus throwing more weight towards the base of the rail.

In Report No. 27 to the Rail Committee, issued in July, 1912, considerable data was published relative to the strength of bases of a number of different 85-lb. ASCE section rails. The present investigation involves data that may be compared with results found in previous report. In that report it was well established that the seams in the base greatly decreased the strength of the base of the rail for sections studied. The results of this investigation are even more conclusive on this point.

For ready reference, contours of the four different rail bases investigated are shown in Fig. 36.

The data include a considerable number of transverse tests on the different rails, as well as on the different rail bases, and can only be appreciated by individual study of results and conditions effecting results.

Results of transverse tests on rail 10062, shown in Table 9, do not show any decided decrease in strength per unit section for specimens at low temperatures. But on these tests, the bases were planed so that no seams were present. Results of transverse tests on rail 12101 for effect of temperature show considerable decrease of strength per unit section, with reduction of 70 degrees in temperature. These tests were made on specimens with the base containing some per cent of seams, even though the bases had been planed, and lead to the conclusion that the effect of lowering temperature is most marked in decreasing the strength of the rail when rail contains defects.

The average results of all transverse tests are shown in Table 11. From the results of the average values, calculated values have been given per linear inch for the full base of the rail, not only for the specimens tested with a thickness of 0.4 in., but also for those tested with a thickness of 0.8 in. These calculated values agree fairly well for the two different heights of test specimens, and allow a charitable comparison of results.

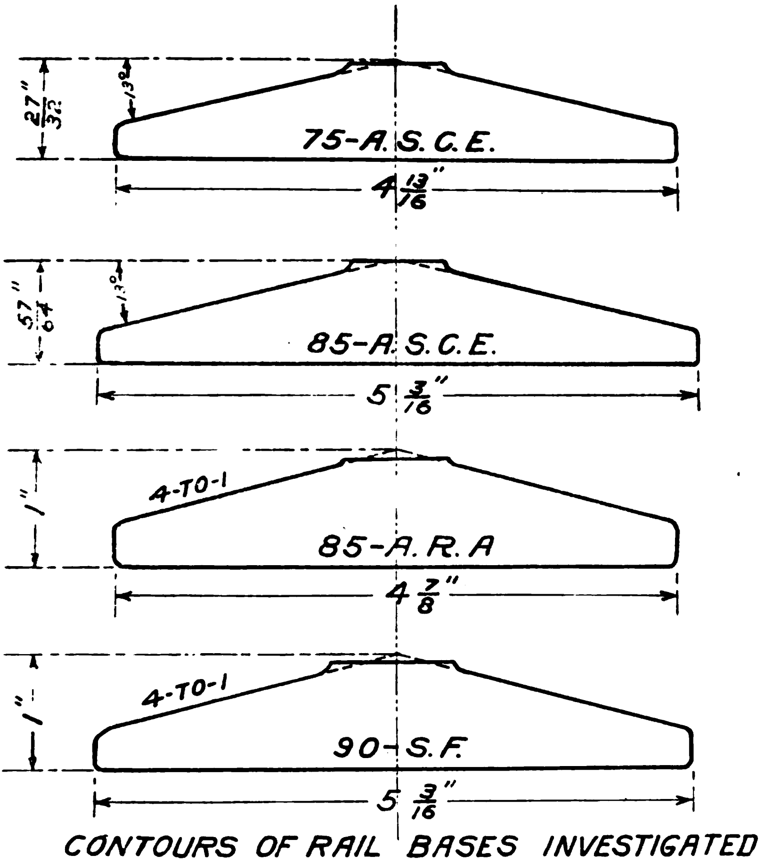


FIG. 36.

From this data it will be seen that rail 15018 and rail 20057 show the greatest strength. These are rail bases from 90-lb. Santa Fe type rails. Rail 33015, although showing great irregularity in structure gives the next best average results for strength of base considering two conditions—base planed and base natural.

CONCLUSIONS.

A careful study of detailed and average results obtained from this investigation concerning laminations in base of rails, leads to certain general conclusions:

1. Rails failing in track may generally be found to contain, upon investigation, numerous black seams in the base.
2. Base seams are not continuous throughout a rail and vary in depth at different intervals.
3. Seams materially decrease tensile properties of the metal in the rail base.
4. Seams decrease strength of rail bases for decreased temperatures.
5. Transverse strength of rail base is decreased about 10 per cent, due to seams in the base.
6. The seams in the rail base may be periodical, due to methods of manufacture causing variation in tensile properties at different portions of the rail.

To reduce rail breakage efforts have been made to increase the rail section, when probably the decreased strength of the rail is due more to physical defects contained therein, than to the weight of the sections. More attention should be given to the elimination of base seams and the direct production of a rail with a uniform homogeneous structure.

SEAMS IN RAILS AS DEVELOPED FROM CRACKS IN THE INGOT.

By M. H. WICKHORST, Engineer of Tests, Rail Committee.

This report covers a study of the development of seams in billets and rails from cracks in the surface of the ingot. From a pile of cold ingots, one was selected which showed a number of cracks on the sides and it was selected because of its bad surface appearance with the idea of determining what form the cracks in the ingot take in the various stages of reduction to the finished rail. In order to show up well the condition of the surface of the ingot below the scale, the four sides of the ingot were "skinned" off in a planer and photographed. Photographs were also made of the surfaces of several of the shapes derived from this ingot.

The work was done at South Bethlehem, Pa., at the works of the Bethlehem Steel Co., who kindly furnished all the material and facilities for the investigation. The ingot selected was from heat 16229, which showed the following heat analysis: C, .57; P, .026; S, .035; Mn, .52; Si, .093. After lightly planing the four sides, the dimensions of the ingot were as follows: 82½ inches high, 18⅝x22½ inches at the bottom end, and 17x20½ inches at the top end.

One of the narrow sides was designated the top side and was marked by drilling a three-inch hole about two inches deep, into the top end. This was the upper side as the ingot first entered the rolls with the top end of the ingot forward. Standing at the bottom end of the ingot and looking toward the top end, the side at the right was designated the right side and the side at the left was designated the left side.

For convenience of description the work may be divided into several stages, as follows:

First Stage—The four sides of the ingot were skinned off in a planer and photographed.

Second Stage—The ingot was run through blooming rolls with the long diameter vertical and reduced from 22½ inches to 16½ inches in two passes and then allowed to cool. The resulting bloom was 8 ft. 5 in. long, 16½ inches high, 19⅜ inches wide at the bottom end and 18 inches wide at the top end. The sides were concave about ⅝ inch on each side. Photographs were taken of the right, left and top sides of the bloom as rolled and also of the top side after machining off the rough surface.

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Third Stage—The bloom was given one turn to the right, that is, what was the top side of the ingot, now made the right side of the bloom. It was reduced from about 19 inches down to about 10 inches in four passes. This bloom was therefore given a total of 6 passes and was turned once from the ingot. It was cut in two hot by shearing and the two parts of the bloom were measured after cooling. The top part was 6 ft. 6 in. long, 10⅜ inches high and 18¼ inches wide. The bottom part was 6 ft. 9 in. long, 10⅜ inches high and 18½ inches wide. The sides were concave about ⅞ inch on each side.

Fourth Stage—The two parts of the previous bloom were again turned so that what was the top side of the ingot again made the top

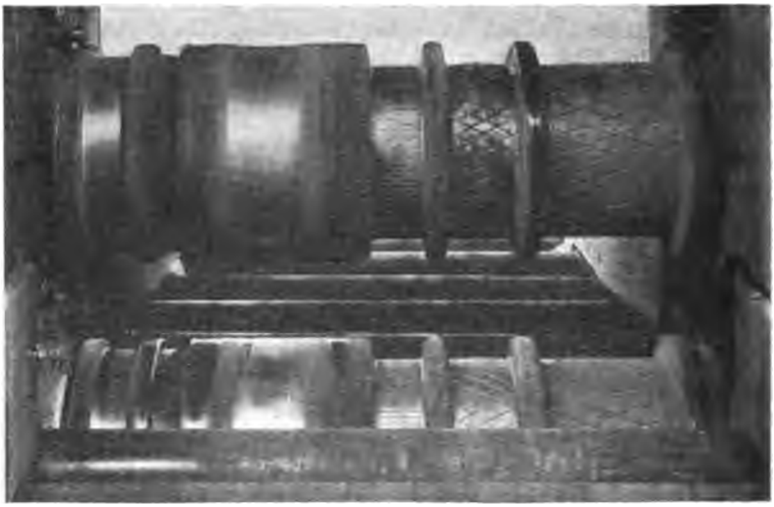


Fig. 1—Blooming Rolls.

side of the bloom as rolled. The 18½-inch dimension was vertical and was brought down to 10 inches in four passes. This made a total of 10 passes and the bloom was turned twice. Each part was again cut in two and the ingot thus made a bloom of four parts. These parts were 10 inches high and 11 inches wide with lengths as follows: part 1, 5 ft.; part 2, 5 ft. 10 in.; part 3, 5 ft. 5 in.; part 4, 6 ft. 3 in.

Fifth Stage—Part 2 of the 10x11 bloom from the fourth stage was worked down to a 7x7-inch bloom, using 8 passes thus making a total of 18 passes from the ingot. When cold this bloom measured 7⅛ in. x 7⅛ in. x 11 ft. 10 in. long and it was sawed into three pieces. The bloom pieces were well pickled in sulphuric acid before photographing.

Sixth Stage—Part 1 of the 10x11 bloom from the fourth stage was worked down to a 5x5-inch bloom using 12 passes, thus making a total of 22 passes from the ingot. When cold it measured 5 in. x 5 in. x 19 ft. 5 in. long and it was sawed into four pieces. These pieces were well pickled before photographing.

Seventh Stage—Part 3 of the 10x11 bloom from the fourth stage was bloomed to 8x8 inches in four passes and this at once rolled into 85 lb. A. S. C. E. section rails in 11 passes, making a total of 25 passes from the ingot to the rail. It was rolled so that what was the top side of the ingot finally made the bottom side or base of the rail. The rail-bar was 57 ft. long, cut into four-foot pieces and well pickled.

Eighth Stage—Part 4 of the 10x11 bloom from the fourth stage was rolled into rail in the same manner as part 3, just described, except that what was the top side of the ingot finally made the left side of the rail. That is, the left side of the ingot made the base of the rail and the right side of the ingot made the tread of the rail. The rail-bar was 68½ ft. long, cut into four-foot pieces and pickled.

The blooming mill was two-high with variable draft and the larger blooming passes were respectively 20 in., 10 in. and 8 in. between collars. A view of the blooming rolls is given in Fig. 1.

The appearance of the "top" side of the ingot (that is, the side on top when first entering the blooming rolls) is shown at various stages from the ingot to the rail in Figs 2 to 9 inclusive. For convenience

FIG. 2—TOP SIDE OF INGOT SKINNED OFF IN PLANER.

FIG. 3—TOP SIDE OF INGOT AFTER TWO PASSES, MAKING TOP SIDE OF BLOOM.

FIG 4—TOP SIDE OF INGOT AFTER TWO PASSES, SURFACE SKINNED OFF IN PLANER.

FIG. 5—TOP SIDE OF INGOT AFTER SIX PASSES AND TURNED ONCE, MAKING RIGHT SIDE OF BLOOM.

FIG. 6—TOP SIDE OF SECOND QUARTER OF INGOT ROLLED INTO 7 x 7 INCH BLOOM. PICKLED.

FIG. 7 TOP SIDE OF TOP QUARTER OF INGOT ROLLED INTO 5 x 5 INCH BLOOM. PICKLED.

Fig 8—Top Side of Third Quarter of Ingot Rolled Into Rail, Making Bottom of Base. Pickled.

FIG. 9—TOP SIDE OF BOTTOM QUARTER OF INGOT ROLLED INTO RAIL, MAKING LEFT SIDE OF RAIL. PICKLED.

of description the main cracks which showed after lightly machining the surface, were numbered from T1 to T12 inclusive (T standing for "top" side). The cracks on the bottom side were numbered and given the prefix "B;" those on the right side were given the prefix "R;" and those on the left side were given the prefix "L." The flaws and cracks found in succeeding shapes were given the same numbers as the cracks in the ingot from which they were derived. Fig. 2 shows the top side of the ingot as skinned off. Fig. 3 shows the top side as rolled, after the thickness had been reduced from about 22 in. to 16 in. in two passes. Crack T12 near the bottom of the ingot shows on this surface, but the others do not show, except perhaps that T11 shows slightly. Fig. 4 shows the same surface planed off lightly and what were the larger cracks in the ingot are now visible. The small ones are no longer visible and the others do not show as prominently, except again, T11, although this does not appear as an open crack. Fig. 5 shows the top side of the ingot at the third stage. The top side is now shown as the right side of the bloom. The cracks do not show, except T12 near the bottom end. Fig. 6 shows the top side of the second quarter of the ingot, rolled to a 7x7-inch bloom and Fig. 7 shows the top side of the

FIG. 10—BOTTOM SIDE OF INGOT SKINNED OFF IN PLANER.

top quarter of the ingot, rolled to a 5x5-inch bloom. These are the surfaces after thorough pickling in sulphuric acid. They show no big flaws except the holes near the top ends drilled in as markers before rolling. Fig. 8 shows the third quarter of the ingot rolled into rail and pickled. The bottom of the base is shown which was the top side of the ingot. A few seams are shown near the side in samples 3F and 3F. Fig. 9 shows the bottom quarter of the ingot rolled into rail and pickled and in this case the top side of the ingot is shown as the left side of the rail. Samples 4A and 4B showed seamy on the side of the web which, however, resulted from holes drilled in the bloom to mark the top side.

The bottom side of the ingot is shown in a somewhat similar manner in Figs. 10 to 15 inclusive, and in this case the cracks in the ingot seem not to have resulted in flaws in the billets or rails.

FIG. 11—BOTTOM SIDE OF INGOT AFTER SIX PASSES AND TURNED ONCE, MAKING LEFT SIDE OF BLOOM.

FIG. 12—BOTTOM SIDE OF SECOND QUARTER OF INGOT ROLLED INTO 7 x 7 INCH BLOOM. PICKLED.

FIG. 13—BOTTOM SIDE OF TOP QUARTER OF INGOT ROLLED INTO 5 x 5 INCH BLOOM. PICKLED.

Fig. 14—Bottom Side of Third Quarter of Ingot Rolled Into Rail, Making Top of Head. Pickled.

FIG. 15—BOTTOM SIDE OF BOTTOM QUARTER OF INGOT ROLLED INTO RAIL. MAKING RIGHT SIDE OF RAIL. PICKLED.

FIG. 16—RIGHT SIDE OF INGOT SKINNED OFF IN PLANER.

FIG. 17—RIGHT SIDE OF INGOT AFTER TWO PASSES, MAKING RIGHT SIDE OF BLOOM.

Fig. 16 shows the right side of the ingot planed off lightly. Fig. 17 shows the same side after the first reduction from 22 to 16 inches in two passes. This is the rough surface and it will be noticed that the cracks have all been opened up and now "yawn" open, in which respect the cracks on the side of the ingot acted quite differently from those on the top and bottom sides which were in contact with the rolls. From this difference, the interesting conclusion seems to follow that *the metal ahead of the rolls is compressed while that between the rolls is pulled.* Fig. 18 shows the right side of the ingot after it was given a total of

FIG. 18—RIGHT SIDE OF INGOT AFTER SIX PASSES AND TURNED ONCE, MAKING BOTTOM SIDE OF BLOOM.

six passes and was turned once so that it made the bottom of the bloom. The various cracks are plainly seen, although somewhat "smeared" over. Fig. 19 shows the right side of the ingot in the fourth

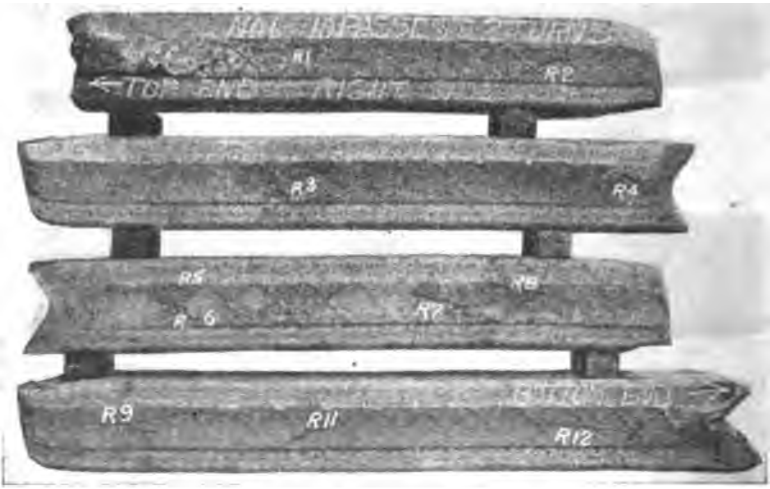


FIG. 19—RIGHT SIDE OF INGOT AFTER TEN PASSES AND TURNED TWICE, MAKING RIGHT SIDE OF BLOOM.

stage after a total of ten passes and again turned so that what was the right side of the ingot made also the right side of the bloom, now 11 in. wide by 10 in. high. The cracks which were opened up in the first blooming have become elongated, but did not pull open farther

FIG. 20—RIGHT SIDE OF SECOND QUARTER OF INGOT ROLLED INTO 7 X 7 INCH BLOOM. PICKLED.

The sides of the opening have come together so as to make a longitudinal crack or seam with two branches issuing from it, thus making a Y seam. This is well illustrated by crack R 9. Fig. 20 shows the right side of the second quarter of the ingot rolled to a 7x7-inch bloom. What were cracks R 3 and R 4 in the ingot are here seen as consisting largely of elongated Y seams. Fig. 21 shows the right side of the top quarter of the ingot rolled to a 5x5-inch bloom. What was crack R 2 is here seen as an elongated Y seam. Fig. 22 shows the right side of the third quarter of the ingot rolled into 85 lb. A. S. C. E. section rail. The right side of the ingot made the left side of the rail. Although considerably changed, we may even here recognize what were cracks in the ingot as seams, mostly as very much elongated Y seams. Fig. 23 shows the right side of the bottom quarter of the ingot rolled into 85-lb. rail and in this case, the right side made the top of the rail. Here

FIG. 21—RIGHT SIDE OF TOP QUARTER OF INGOT ROLLED INTO 5 X 5 INCH BLOOM. PICKLED.

again we may recognize what were cracks in the ingot as seams in the head of the rail.

The surface of the left side of the ingot is shown in Figs. 24 to 31 inclusive at the various stages in the same manner as shown for the right side. Here again we see that the cracks of the ingot which were transverse of the ingot or obliquely so, first opened up as double V's, one within the other, then formed into Y-shaped flaws lengthwise of the bloom and finally developed as very much elongated Y seams in the rail. Fig. 31 shows the left side of the bottom quarter of the ingot rolled into the base of the rail, showing the presence of numerous seams. The base of the piece of rail marked 4 C, shown in this illustration, was broken lengthwise to show the seam and this is shown in Fig. 32. The seam here shown was 1/8 inch deep.

From the above descriptions it will be seen that cracks in the right or left side of the ingot as it first entered the blooming rolls finally developed into seams in the rail, mostly of elongated Y form several feet long, while most of the cracks in the top or bottom side of the ingot as it first entered the blooming rolls, disappear so far as may be

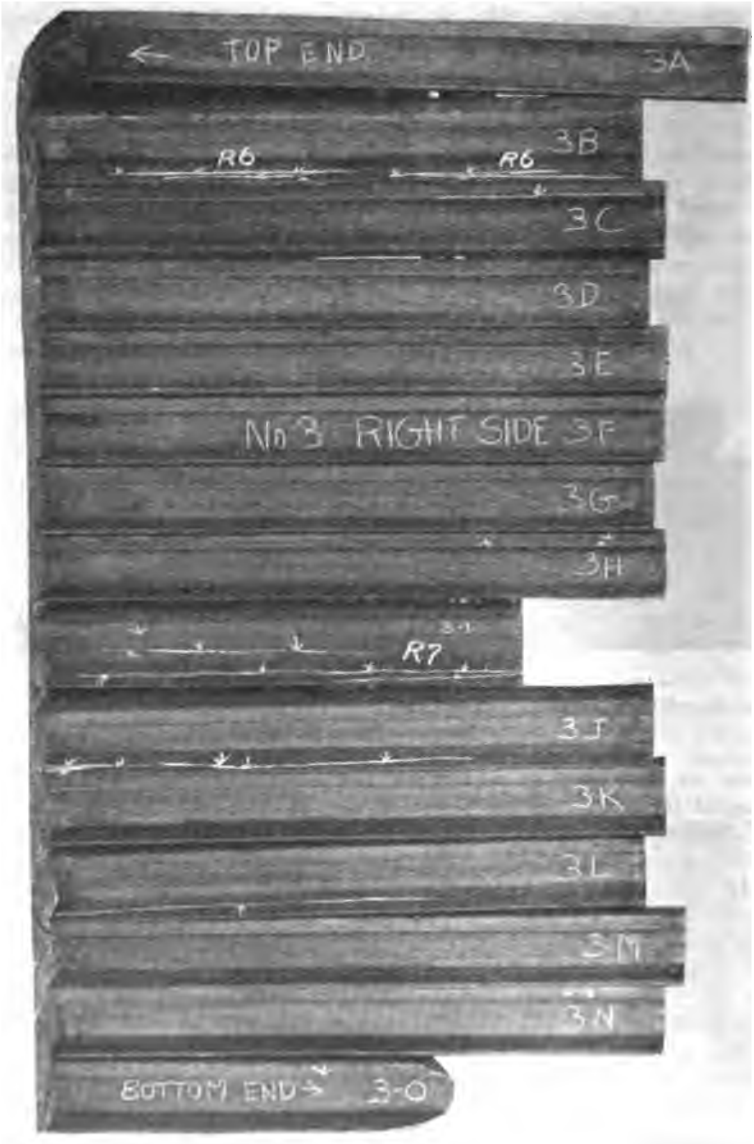


FIG. 22—RIGHT SIDE OF THIRD QUARTER OF INGOT ROLLED INTO RAIL, MAKING LEFT SIDE OF RAIL. PICKLED.

FIG. 23—RIGHT SIDE OF BOTTOM QUARTER OF INGOT ROLLED INTO RAIL, MAKING TOP SIDE OF RAIL. PICKLED.

FIG. 24—LEFT SIDE OF INGOT SKINNED OFF IN PLANER.

FIG. 25—LEFT SIDE OF INGOT AFTER TWO PASSES, MAKING LEFT SIDE OF BLOOM.

FIG. 26—LEFT SIDE OF INGOT AFTER SIX PASSES AND TURNED ONCE, MAKING TOP SIDE OF BLOOM.

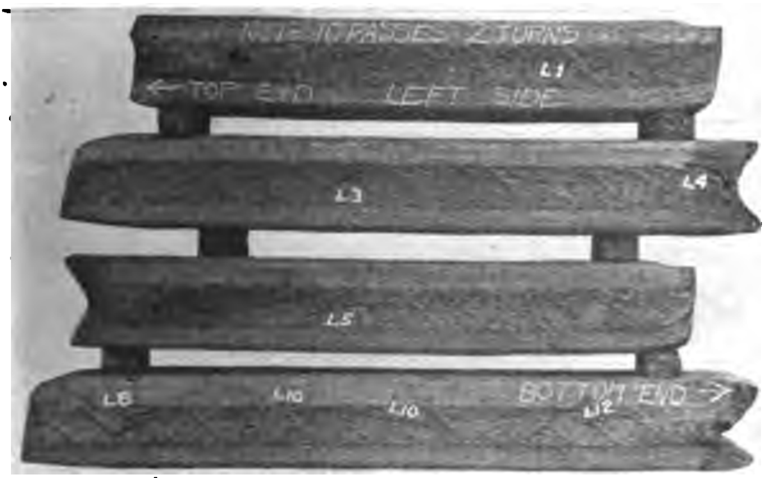


FIG. 27—LEFT SIDE OF INGOT AFTER TEN PASSES AND TURNED TWICE, MAKING LEFT SIDE OF BLOOM

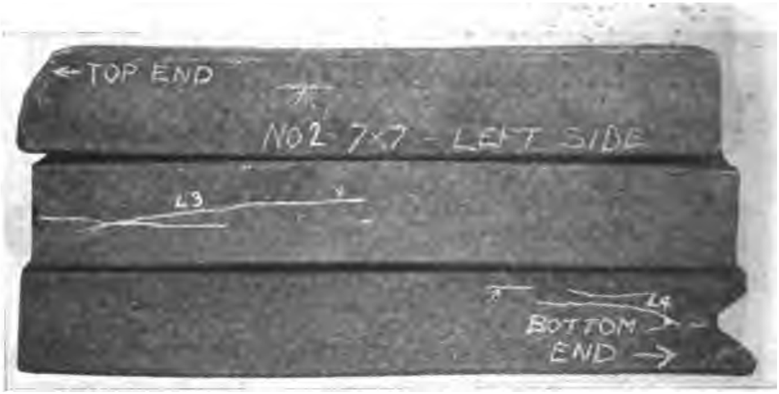


FIG. 28—LEFT SIDE OF SECOND QUARTER OF INGOT ROLLED INTO 7 X 7 INCH BLOOM. PICKLED.

FIG. 29—LEFT SIDE OF TOP QUARTER OF INGOT ROLLED INTO 5 X 5 INCH BLOOM. PICKLED.

FIG. 30—LEFT SIDE OF THIRD QUARTER OF INGOT ROLLED INTO RAIL, MAKING RIGHT SIDE OF RAIL. PICKLED.

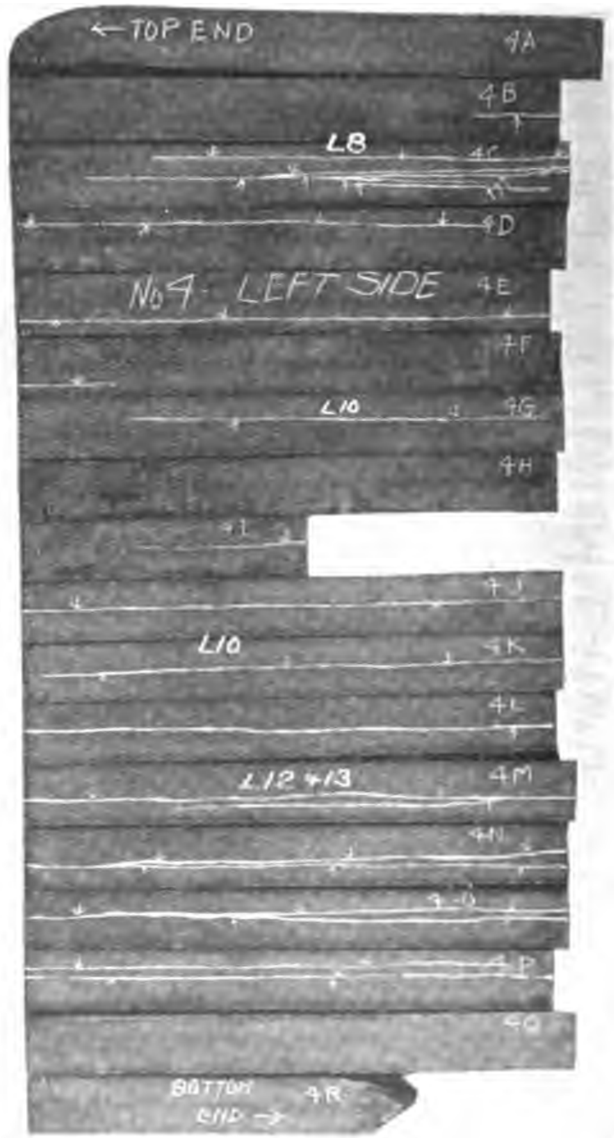


FIG. 31—LEFT SIDE OF BOTTOM QUARTER OF INGOT ROLLED INTO RAIL, MAKING BOTTOM OF RAIL PICKLED

shown by the appearance of the surface or developed by pickling in acid. It seems to be true that from the standpoint of rail failures, the most detrimental location of a seam is at or near the center of the bottom of the base and the above observation suggests that the base may be at least partly or perhaps mostly freed from injurious seams by mak-

FIG. 32—VERTICAL LONGITUDINAL FRACTURE OF FLANGE, SHOWING LONGITUDINAL SEAM IN BOTTOM OF BASE.

ing the top or bottom side of the ingot as it first enters the blooming rolls form the bottom of the base.

In order to show in convenient form the development of seams from cracks in the ingot, Fig. 33 is presented. A crack first opens up

FIG. 33—DIAGRAMS SHOWING DEVELOPMENT OF SEAMS IN RAILS FROM CRACKS IN THE INGOT.

forming two V's, one inside the other. These are both elongated and closed in, forming a Y in the bloom. This continues to be elongated and finally forms a long narrow Y, perhaps several feet long. This is the simplest case, but the more usual case consists of a cluster of elongated Y's of varying lengths.

SUMMARY.

1. An investigation was made concerning the development of seams in billets and rails from cracks in the surface of the ingot. A cold ingot with a badly cracked surface was taken and its four sides "skinned" off in a planer to show well the condition of the surfaces. The four sides were photographed and photographs were also made at succeeding stages showing the surfaces of blooms and rails.

2. The work was done at South Bethlehem, Pa., at the works of the Bethlehem Steel Co., who kindly furnished all the facilities and material for this work.

3. The cracks in the ingot were, in a general way, transverse or obliquely transverse of the ingot. When first bloomed, the cracks on the right and left sides of the ingot as it first entered the blooming rolls, opened up or "yawned" open, forming double V's, one inside the other. Further blooming elongated and closed in the cracks, forming them into elongated Y-shaped flaws, or clusters of them. Still further rolling finally resulted in long narrow Y-shaped seams in the rail, or clusters of them, generally several feet long, as shown up by pickling in sulphuric acid.

4. The cracks on the top and bottom sides of the ingot as it first entered the rolls, did not open up and finally disappeared so far as could be determined by the appearance of the surfaces of the blooms and rails after pickling in sulphuric acid.

5. The difference in behavior of the cracks on the top and bottom sides in rolling from the behavior of those on the right and left sides suggests the interesting conclusion that the metal ahead of the rolls is compressed, while that between the rolls is pulled.

6. The work indicated that seams resulting from cracks in the ingot will be on the web of the rail if what were the right and left sides of the ingot as it first entered the rolls form the sides of the rail, and that they will be on the top of the head and the bottom of the base if these sides of the ingot form the tread and base of the rail.

7. To sum up, the cracks on the right and left sides of the ingot as it first entered the blooming rolls, resulted in seams in the rails, while the cracks on the top and bottom sides of the ingot did not result in seams. Seams may therefore possibly be oriented to appear on the sides of the rail or on the tread and the bottom of the base.

REVISED FORM M. W. 408.

STATISTICS OF RAIL FAILURES

FOR ONE YEAR.

DIRECTIONS FOR FILLING IN THIS FORM

1. Statistics are desired of rails weighing 70 lbs. per yard and
2. Fill in the information concerning rail lots in which there were failures.
3. Rails broken or injured by
report

INFORMATION IN
REGARD TO
SPLICE BARS.

Appendix F.

INFLUENCE OF ALUMINUM AND SILICON ON BESSEMER INGOTS AND RAILS.

By M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation concerning the influence of aluminum on bessemer steel ingots and rails when added to the molds while pouring the steel and at the same time some tests were made on the influence of silicon on bessemer rails when added as ferro-silicon to the molds. Four ingots were selected from a heat of bessemer steel for splitting and chemical survey. One ingot was of plain untreated steel and the others were of steel treated with various amounts of aluminum. Rails were also made of two other ingots from the heat, one plain and the other aluminum-treated. In addition rails were made from two other heats. Some of the ingots were plain untreated and others were treated with aluminum or ferro-silicon while pouring the steel into the molds. The rails were cut up for drop tests and transverse tests of the base. The work was done at South Chicago, Ill., at the works of the Illinois Steel Co., who kindly furnished all the material and facilities for the investigation.

MANUFACTURE.

The steel was made by blowing mixer metal and scrap steel, adding spiegel to the converter and then pouring the metal into an intermediate ladle. The metal was then poured into the teeming ladle and finally into the ingot molds. In the third heat used, it was desired to have the carbon a little above the usual amount, and the additional carbon was obtained by adding some liquid mixer iron to the converter after blowing, along with the spiegel. The amounts in pounds, of the various materials used, are shown in table 1.

TABLE 1—AMOUNTS OF MATERIAL USED.

Heat number	28,619	28,630	34,503
Date made	July 12, 1913	July 12, 1913	July 21, 1913
Mixer metal	28,000	29,000	27,000
Scrap steel	1,500	500	2,000
Spiegel	2,990	2,990	3,400
Mixer metal to recarbonize	.....	.....	440

In all, fifteen ingots were used in this investigation and table 2 is given showing the heat from which each was made, its treatment and purpose for which used.

Report No. 39, October, 1913.

TABLE 2—INGOTS USED.

Ingot No.	Heat No.	Treatment	How Used
1	28,619	1 oz. Al. per T.	Split and surveyed
2	28,619	none	Split and surveyed
3	28,619	2 oz. Al. per T.	Split and surveyed
4	28,619	5 oz. Al. per T.	Split and surveyed
5	28,619	none	85 lb. rails
6	28,619	2 oz. Al. per T.	85 lb. rails
7	28,630	none	85 lb. rails
8	28,630	5 oz. Al. per T.	85 lb. rails
9	34,503	none	90 lb. rails
10	34,503	2 oz. Al. per T.	90 lb. rails
11	34,503	5 oz. Al. per T.	90 lb. rails
12	34,503	10 oz. Al. per T.	90 lb. rails
13	34,503	.1% Si. additional	90 lb. rails
14	34,503	.2% Si. additional	90 lb. rails
15	34,503	none	90 lb. rails

The aluminum used was "shot" aluminum. When the ingot was about one-third poured the addition of aluminum was started and was completed when the ingot was about two-thirds poured. The silicon was added as 50 per cent. ferro-silicon and was added in the same way. Plain ingots 2, 5, 7 and 9 set with somewhat raised tops. The other plain ingot 15, and all the treated ingots set with flat tops. The molds were 18x19 inches at the bottom and had been sprayed with tar.

The compositions of the mixer irons and of the spiegel on the last heat are shown in table 3 together with the heat analyses.

TABLE 3—ANALYSES.

	C.	P.	S.	Mn.	Si.
Mixer iron, heat 28,619	....	....	....	....	1.38
Mixer iron, heat 28,630	....	....	.030	....	1.50
Mixer iron, heat 34,503	....	.089	.033	....	1.40
Spiegel, heat 34,503	4.58	.090	.009	12.74	1.50
Ladle test, heat 28,619	.43	....	.040	.73	....
Ladle test, heat 28,630	.45	....	.045	.99	....
Ladle test, heat 34,503	.57	.092	.038	.83	.132

INGOTS.

Four ingots of heat 28,619 were set aside to cool after being in the soaking pits 2 hours. No. 2 was an ingot of the plain or untreated steel. No. 1 was treated with 2 oz. aluminum or about 1 oz. per ton. No. 3 was treated with 4 oz. aluminum or 2 oz. per ton and No. 4 was treated with 10 oz. or 5 oz. per ton. These ingots were about 18x19 inches at the bottom and about 57 inches high. No. 1 weighed 4,200 lbs. and the others each weighed 4,300 lbs. They were split across their short diameter by slotting on each side, a little to one side of the axial plane and then breaking with wedges under the steam hammer. The larger part was then

FIG. 1—INGOT NO. 1, TREATED WITH 1 OZ. ALUMINUM PER TON OF STEEL.

FIG. 2—INGOT NO. 2, PLAIN BESSEMER STEEL.

planed down to the axial plane. The planed surfaces of these ingots are shown in Figs. 1, 2, 3 and 4. Ingot No. 2 of plain steel, shown in Fig. 2, it will be noted, contained a large central cavity or pipe in the upper part of the ingot and a large number of small elongated holes along the sides in the upper part. This ingot also had a raised top. The other three ingots, treated with various amounts of aluminum, had somewhat larger pipes but were free from the small elongated holes along the sides. They had small holes at the top under the roof of the ingot, which decreased

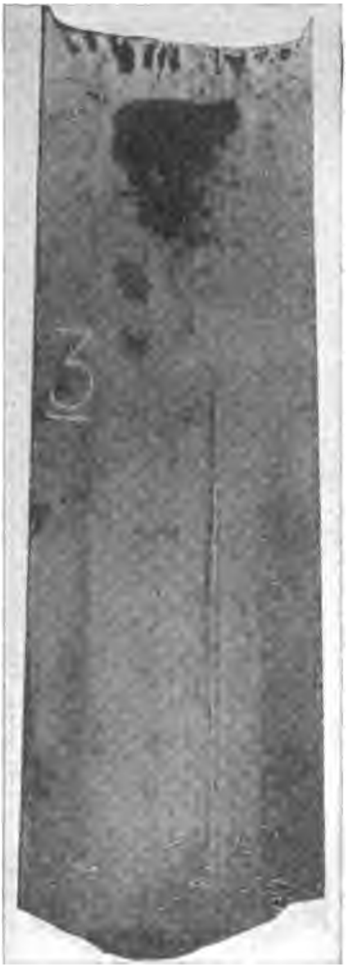


Fig. 3—Ingot No. 3, Treated With 2 Oz. Aluminum Per Ton of Steel.

Fig. 4—Ingot No. 4, Treated With 5 Oz. Aluminum Per Ton of Steel.

in number with increase in amount of aluminum treatment. Ingots No. 1 and No. 3 had some spots in which the fractured surface did not clean up in planing; that is, in splitting, the fractured surfaces were below the central plane in spots and were not afterwards planed off. These spots are marked on the figures with crosses. Ingot No. 3 also shows a large number of dirt and grease spots which are rather confusing. The three aluminum treated ingots had sunken tops. *As disclosed by the appearance of the split ingots, those treated with aluminum had larger pipes but contained denser steel around the pipes.* One oz. of aluminum per ton had

considerable influence in this direction. The effect increased a little with 2 oz. and still a little more with 5 oz. per ton.

ANALYSES OF INGOTS.

A chemical survey was made of each of the ingots by means of drillings taken as shown in Fig. 5. There were five vertical rows of drillings,

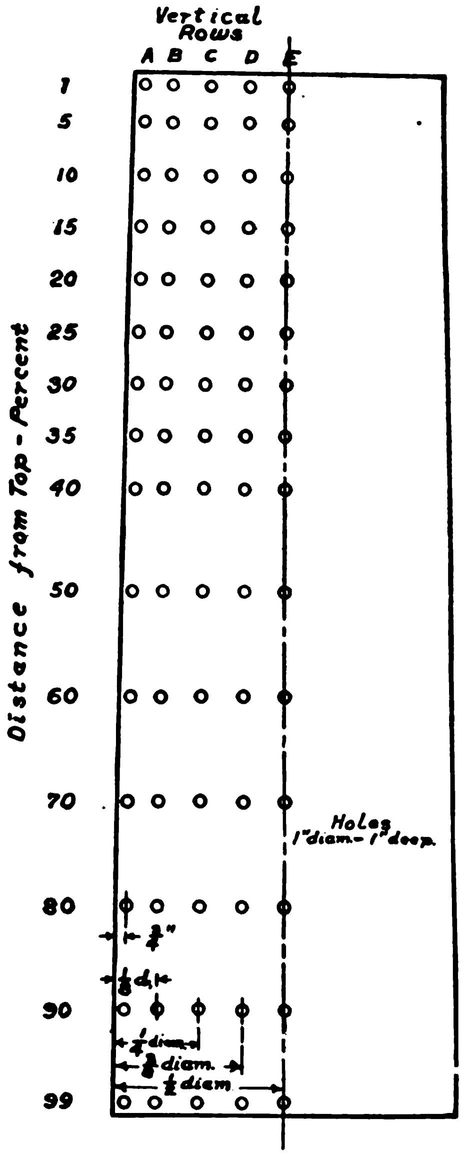


Fig. 5—Drilling Diagram for Ingots.

15 samples for row, from one-half of the section, making a total of 75 samples from each ingot, less the number that could not be obtained due to cavities.

On each sample determinations were made of carbon, phosphorus and sulphur and on the samples from the bottom of the ingot determinations of manganese and silicon also were made. The results on carbon, phosphorus and sulphur are shown in tables 4 to 15 inclusive. The results on manganese and silicon of the five samples from the bottom of each of the ingots are shown in table 16.

TABLE 4—CARBON IN INGOT 1, 1 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.43	.42	..	..	..
5	.44	.45	.44	.44	..
10	.43	.45	.44	..	..
15	.44	.45	.46	..	..
20	.45	.45	.50	..	..
25	.45	.45	.54	.49	..
30	.44	.42	.50	.46	.46
35	.44	.44	.46	.44	.45
40	.45	.45	.44	.44	.45
50	.44	.46	.41	.44	.44
60	.45	.45	.42	.44	.44
70	.45	.45	.42	.43	.44
80	.45	.45	.41	.44	.44
90	.45	.44	.41	.44	.45
99	.45	.45	.44	.44	.45

TABLE 5—PHOSPHORUS IN INGOT 1, 1 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.078	.066	...	...	...
5	.085	.086	.083	.079	...
10	.085	.072	.090	...	...
15	.089	.085	.092	...	...
20	.088	.089	.110	...	...
25	.090	.087	.112	.105	...
30	.089	.089	.103	.100	.101
35	.090	.090	.095	.088	.086
40	.088	.089	.096	.088	.090
50	.088	.089	.088	.084	.083
60	.089	.090	.086	.084	.078
70	.089	.090	.089	.080	.088
80	.089	.092	.091	.081	.079
90	.089	.089	.087	.080	.080
99	.087	.090	.090	.087	.086

TABLE 6—SULPHUR IN INGOT 1, 1 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.030	.023	...	...	...
5	.032	.033	.033	.032	...
10	.031	.027	.035	...	...
15	.033	.032	.038	...	...
20	.034	.038	.045	...	...
25	.037	.034	.048	.045	...
30	.037	.033	.044	.041	.044
35	.037	.037	.041	.036	.036
40	.035	.035	.030	.034	.035
50	.034	.038	.035	.031	.033
60	.036	.036	.034	.032	.031
70	.036	.037	.036	.031	.033
80	.034	.037	.034	.032	.032
90	.037	.038	.035	.032	.034
99	.036	.038	.035	.036	.032

TABLE 7—CARBON IN INGOT 2, PLAIN STEEL.

Per Cent. from Top.	A	B	C	D	E
1	...	...	.36	.34	.32
5	.35	.37	.32	.38	.39
10	.31	.34	.48	...	...
15	.32	.32	.45	...	...
20	.34	.38	.53	.63	.71
25	.38	.38	.49	.54	.61
30	.40	.40	.49	.53	.50
35	.41	.46	.49	.46	.54
40	.41	.46	.48	.45	.53
50	.41	.43	.48	.46	.44
60	.42	.44	.42	.41	.42
70	.43	.43	.44	.42	.39
80	.42	.46	.42	.40	.40
90	.43	.43	.41	.33	.38
99	.44	.42	.46	.36	.43

TABLE 8—PHOSPHORUS IN INGOT 2, PLAIN STEEL.

Per Cent. from Top.	A	B	C	D	E
1	...	...	.062	.061	.061
5	.061	.064	.058	.064	.070
10	.051	.058	.097	...	...
15	.057	.057	.094	...	...
20	.061	.069	.106	.165	.234
25	.078	.068	.092	.126	.175
30	.084	.077	.092	.131	.130
35	.089	.093	.108	.109	.105
40	.090	.091	.108	.102	.107
50	.090	.093	.100	.095	.092
60	.088	.090	.090	.084	.090
70	.089	.089	.089	.077	.072
80	.090	.090	.087	.079	.079
90	.087	.091	.084	.076	.079
99	.088	.089	.087	.084	.086

TABLE 9—SULPHUR IN INGOT 2, PLAIN STEEL.

Per Cent. from top.	A	B	C	D	E
1	...	...	.023	.026	.021
5	.027	.025	.019	.025	.028
10	.021	.025	.037	...	...
15	.024	.025	.036	...	...
20	.025	.030	.049	.076	.128
25	.030	.032	.036	.049	.082
30	.038	.033	.039	.058	.057
35	.037	.041	.047	.048	.046
40	.040	.039	.046	.045	.043
50	.040	.039	.041	.038	.039
60	.040	.040	.036	.038	.037
70	.039	.034	.039	.032	.030
80	.040	.039	.039	.031	.029
90	.039	.038	.036	.032	.034
99	.040	.037	.039	.037	.035

TABLE 10—CARBON IN INGOT 3, 2 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.41	..	..	..	..
5	.40	.43	.37	.35	.43
10	.43	.40	..	..	..
15	.43	.42	..	..	..
20	.43	.43	.50	..	..
25	.43	.43	.49	.52	.66
30	.43	.43	.50	.47	.43
35	.43	.43	.51	.42	.42
40	.43	.43	.48	.38	.41
50	.43	.43	.41	.38	.39
60	.42	.43	.43	.38	.38
70	.44	.44	.42	.39	.37
80	.43	.42	.44	.39	.38
90	.45	.42	.40	.37	.36
99	.44	.43	.42	.43	.41

TABLE 11—PHOSPHORUS IN INGOT 3, 2 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.081	...	...	...	...
5	.087	.087	.069	.068	.092
10	.088	.076	...	...	...
15	.090	.091	...	...	...
20	.088	.095	.088	...	...
25	.090	.092	.100	.118	.205
30	.090	.089	.110	.094	.098
35	.090	.093	.095	.081	.081
40	.091	.090	.092	.086	.076
50	.089	.093	.090	.083	.075
60	.089	.092	.086	.087	.075
70	.088	.091	.086	.081	.077
80	.089	.090	.087	.081	.077
90	.089	.089	.082	.077	.080
99	.090	.091	.088	.086	.086

TABLE 12—SULPHUR IN INGOT 3, 2 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.033	...	...	...	...
5	.034	.033	.028	.030	.038
10	.036	.032	...	...	...
15	.035	.036	...	...	...
20	.032	.038	.039	...	...
25	.036	.035	.046	.057	.081
30	.040	.037	.047	.040	.043
35	.038	.040	.039	.037	.038
40	.037	.040	.042	.038	.035
50	.035	.040	.032	.033	.031
60	.038	.039	.035	.033	.030
70	.035	.036	.040	.041	.032
80	.035	.035	.036	.033	.036
90	.033	.038	.032	.034	.031
90	.039	.038	.037	.038	.032

TABLE 13—CARBON IN INGOT 4, 5 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.45	.45	..	.43	.43
5	.45	.43	..	..	..
10	.46	.46	..	..	..
15	.45	.44	.50	..	..
20	.42	.44	.54	.54	..
25	.42	.47	.53	.49	.46
30	.41	.44	.52	.43	.45
35	.42	.44	.47	.40	.44
40	.43	.44	.48	.43	.46
50	.43	.44	.42	.40	.38
60	.43	.43	.44	.40	.41
70	.42	.44	.43	.41	.41
80	.42	.45	.42	.41	.40
90	.43	.43	.42	.40	.40
99	.43	.44	.45	.46	.42

TABLE 14—PHOSPHORUS IN INGOT 4, 5 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.093	.088	...	.078	.080
5	.093	.089	...	...	...
10	.093	.091	...	...	...
15	.095	.091	.101	...	...
20	.094	.092	.113	.118	...
25	.094	.091	.113	.106	.083
30	.094	.092	.105	.092	.084
35	.091	.092	.101	.086	.087
40	.094	.092	.094	.090	.092
50	.093	.091	.092	.089	.081
60	.094	.092	.090	.084	.085
70	.093	.091	.094	.086	.081
80	.094	.092	.091	.083	.077
90	.092	.092	.086	.087	.085
99	.094	.090	.093	.093	.087

TABLE 15—SULPHUR IN INGOT 4, 5 OZ. ALUMINUM PER TON.

Per Cent. from Top.	A	B	C	D	E
1	.039	.035	...	.028	.031
5	.038	.036	...	...	...
10	.036	.036	...	...	...
15	.037	.038	.039	...	...
20	.038	.037	.045	.048	...
25	.038	.035	.044	.037	.038
30	.039	.037	.044	.037	.035
35	.037	.038	.039	.034	.035
40	.039	.037	.037	.034	.037
50	.039	.039	.035	.034	.035
60	.037	.038	.037	.032	.030
70	.039	.038	.036	.034	.032
80	.040	.034	.035	.036	.030
90	.039	.038	.034	.033	.032
99	.039	.040	.035	.035	.032

TABLE 16—MANGANESE AND SILICON IN INGOTS.

	99A	99B	99C	99D	99E	Av.
Manganese, Ingot 1..	.69	.67	.69	.67	.66	.676
Manganese, Ingot 2..	.69	.70	.71	.69	.70	.698
Manganese, Ingot 3..	.70	.69	.68	.73	.69	.698
Manganese, Ingot 4..	.68	.68	.68	.68	.69	.682
Manganese, Average.						.689
Silicon, Ingot 1.....	.127	.120	.130	.128	.123	.126
Silicon, Ingot 2.....	.128	.127	.130	.126	.128	.128
Silicon, Ingot 3.....	.125	.107	.117	.127	.120	.119
Silicon, Ingot 4.....	.119	.120	.123	.122	.122	.121
Silicon, Average.....						.124

Probably the five samples along the bottom of the ingot represent fairly closely the average steel of the ingot and in table 17 are given the average composition of each ingot, the general average, and for comparison, the heat analysis.

TABLE 17—AVERAGE STEEL IN INGOTS.

	C.	P.	S.	Mn.	Si.
Ingot 1...............	.446	.088	.035	.676	.126
Ingot 2...............	.438	.087	.038	.698	.128
Ingot 3...............	.426	.088	.037	.698	.119
Ingot 4...............	.440	.091	.036	.682	.121
Average	.438	.089	.037	.689	.124
Heat analysis, 28,619..	.43		.040	.73	

At any given distance from the top of the ingot the extreme variations in composition are in general shown by the axis and the walls of the ingot and to show conveniently the changes from the top to the bottom of the ingot, the carbon, phosphorus and sulphur are plotted in Figs. 6, 7, and 8 respectively, each figure showing one element for each of the four ingots. The distance from the top of the ingot in per cent. of the height is shown horizontally and the amount of the element is shown vertically. Where samples could not be obtained from the axis because of

cavities, the results were taken from samples next the cavities and in a few other cases also, the results were taken from samples away from the axis in order to better show up the maximum amount of the elements

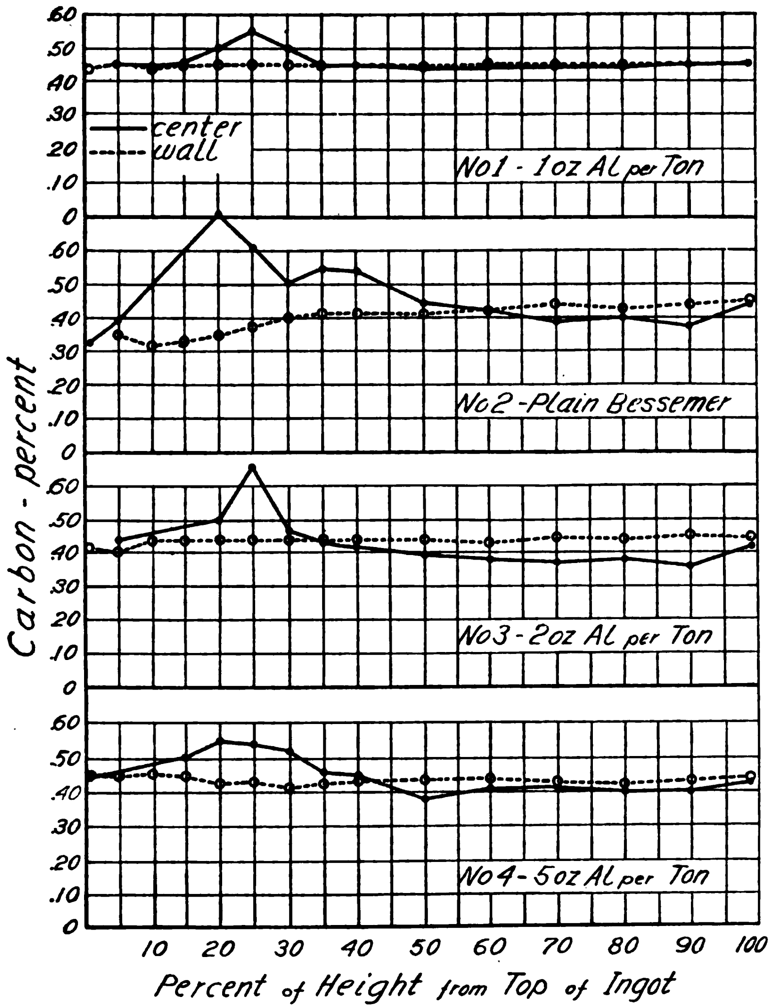


FIG. 6—CARBON DIAGRAMS OF INGOTS.

in the upper and interior part of the ingot It will be noted that in the aluminum treated ingots, the walls showed a fairly even composition throughout the heights of the ingots. In the ingot of plain bessemer steel, the wall at the top end showed considerably less carbon, phosphorus and

sulphur than the average of these elements in the ingot. These elements increased in the wall, downward of the ingot until at about 30 per cent. of the height from the top end, the average composition was reached, and it then remained about uniform for the rest of the distance downward.

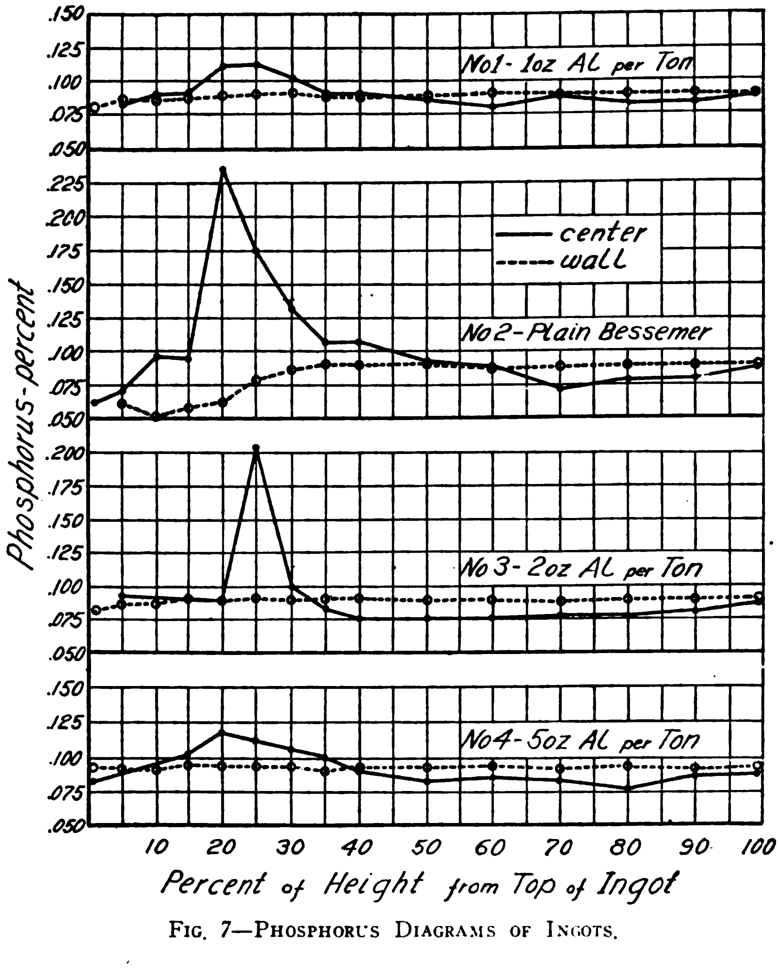


FIG. 7—PHOSPHORUS DIAGRAMS OF INGOTS.

The interior metal showed a segregation or concentration of the elements in the upper part of the ingot, reaching a maximum at about 20 or 25 per cent. from the top. The segregation was considerable in the plain bessemer steel, less in the steel treated with 2 oz. aluminum per ton, and mild in the steels treated with 1 oz. and with 5 oz. aluminum per ton. In all the ingots, the lower half of the ingot showed "soft centers," that is

the carbon, phosphorus and sulphur in the interior were below the average composition of the steel.

The maximum amounts of positive segregation found in the interior of the several ingots and the per cents of increase above the average com-

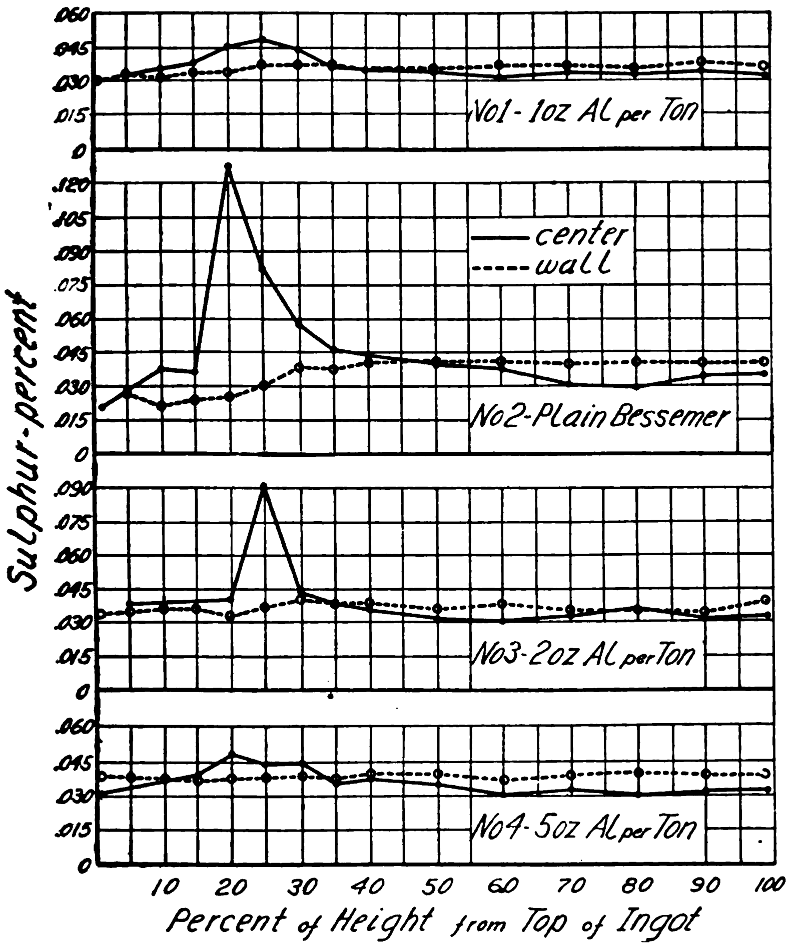


FIG. 8—SULPHUR DIAGRAMS OF INGOTS.

position of the steel, are shown in table 18. The average results of the four ingots, as shown in table 17 were taken as the average composition of the steel, namely; carbon, .44 per cent.; phosphorus, .089 per cent.; sulphur, .037 per cent.

TABLE 18—POSITIVE SEGREGATION IN INTERIORS OF INGOTS.

Ingot Number.	Maximum Amount.			Per Cent. Increase.		
	C.	P.	S.	C.	P.	S.
1—1 oz. aluminum per ton	.54	.112	.048	23	26	30
2—Plain bessemer.......	.71	.234	.128	61	163	246
3—2 oz. aluminum per ton	.66	.205	.081	50	130	119
4—5 oz. aluminum per ton	.54	.118	.048	23	33	30

The maximum amounts of negative segregation found in the walls of the several ingots and the per cents of decrease below the average composition of the steel, are shown in table 19.

TABLE 19—NEGATIVE SEGREGATION IN WALLS OF INGOTS.

Ingot Number.	Minimum Amount.			Per Cent. Decrease.		
	C.	P.	S.	C.	P.	S.
1—1 oz. aluminum per ton	.43	.078	.030	2	12	19
2—Plain bessemer.......	.31	.051	.021	30	43	43
3—2 oz. aluminum per ton	.40	.081	.032	9	9	14
4—5 oz. aluminum per ton	.41	.091	.036	7	2*	3

*Increase

The separation of the phosphorus into regions of different concentrations is shown in fig. 9 for each of the four ingots and the same dia-

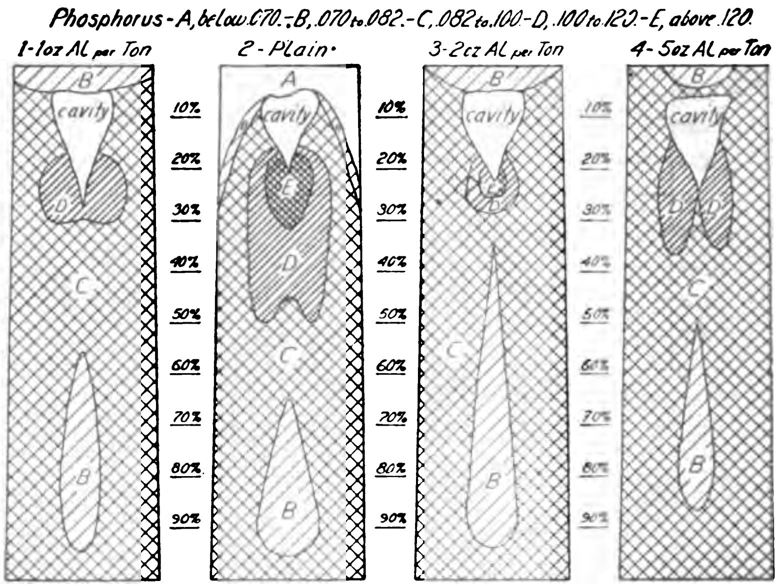


FIG. 9—DISTRIBUTION OF PHOSPHORUS IN THE SEVERAL INGOTS.

grams may be taken to represent the distribution of the carbon and sulphur. Five concentrations of phosphorus were selected as shown in table 20 and the approximate amounts of carbon and sulphur represented by these regions are also shown in the same table.

TABLE 20—REGIONS OF VARIOUS CONCENTRATIONS.

	Phosphorus.	Carbon.	Sulphur.
A	Below .070	Below .35	Below .027
B	.070 to .082	.35 to .41	.027 to .033
C	.082 to .100	.41 to .48	.033 to .043
D	.100 to .120	.48 to .58	.043 to .060
E	Above .120	Above .58	Above .060

In this table region C represents steel of about the average composition as poured.

It will be noted that the greatest separation occurred in the ingot of plain steel. The interior positive segregation was greatest and the negative segregation in the wall extended downward very much farther. In

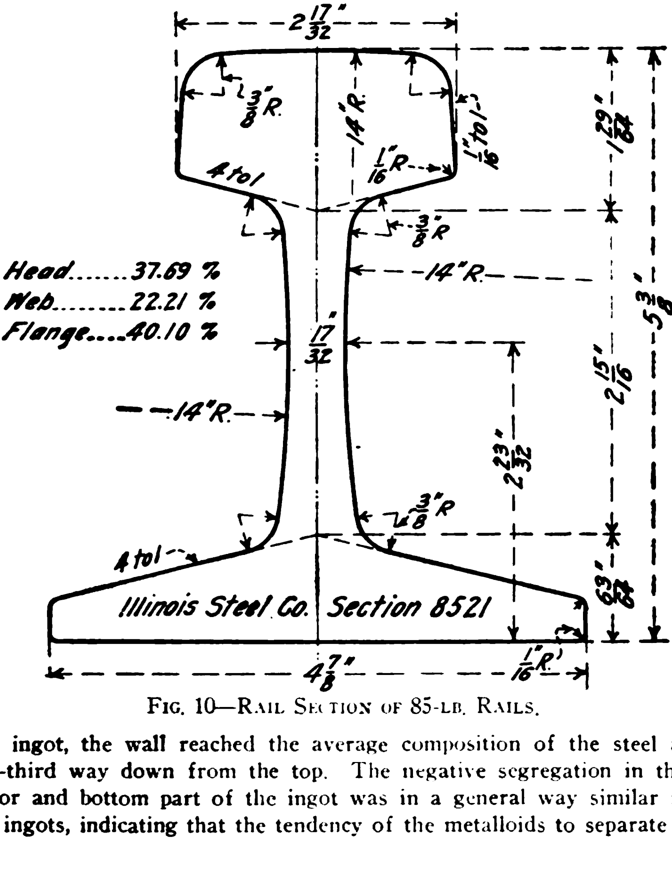


FIG. 10—RAIL SECTION OF 85-LB. RAILS.

this ingot, the wall reached the average composition of the steel about one-third way down from the top. The negative segregation in the interior and bottom part of the ingot was in a general way similar in all the ingots, indicating that the tendency of the metalloids to separate from

this region was not influenced greatly by the aluminum treatment. In the upper half of the ingot, the distribution of the metalloids was more even in the aluminum treated ingots than in the plain steel, and the distribution was roughly the same for the various amounts of aluminum treatment between 1 oz. and 5 oz. per ton.

RAILS.

As shown in table 2, ingots 5, 6, 7 and 8 were rolled into 85 lb. rails and ingots 9 to 15 inclusive were rolled into 90 lb. rails. The ingots were about 18x19 inches at the bottom, were bloomed in 9 passes and finished in 9 more passes, making a total of 18 passes from the ingot to the rail. After blooming only such croppings were made from the ends of the blooms as were necessary to permit of the bars going through the rolls satisfactorily. Each ingot made four rails. No croppings were made from the rail-bars but the rough ends were left on the rails. In the case of the 85 lb. rails, the blooms were cut in two before shaping into rail, and in the case of the 90 lb. rails the blooms were rolled into rail without cutting. The 85 lb. rails were of the Illinois Steel Company's section 8521, shown in Fig. 10. The 90 lb. rails were of the A. R. A. type A section. (For diagram of this section see Proceedings American Railway Engineering Association, 1911, Vol. 12, part 2, page 153.)

The weights of the rails and bloom crops of the several ingots are shown in table 21.

TABLE 21—WEIGHTS OF RAILS AND BLOOM CROPS.

Ingot Number.	Top Crop.	A Rail.	B Rail.	C Rail.	D Rail.	Bottom Crop.	Total Ingot.
5	75	983	981	1022	1068	100	4229
6	71	1001	949	1027	1125	80	4253
7	80	1006	978	1036	1153	127	4380
8	101	1044	956	1055	1170	105	4431
9	90	1080	992	992	970	145	4269
10	123	1070	988	990	1030	255	4456
11	76	1010	988	990	1010	235	4309
12	128	988	988	988	1045	225	4362
13	87	935	990	988	1032	214	4246
14	107	1042	986	990	1022	228	4375
15	130	1010	990	988	1045	216	4379

Samples for analysis as representing the averages of the rail-bars were taken from near the top end of each of the D rails by drillings into the top of the head. The samples were taken from the D1 pieces used for transverse base tests and the results are shown in table 22 together with the ladle analyses.

TABLE 22—ANALYSES OF RAILS.

Heat.	Sample.	C.	P.	S.	Mn.	Si.
28,619	5 D 1	.43	.095	.038	.71	.132
28,619	6 D 1	.44	.096	.039	.70	.126
28,619	Ladle	.43	...	.040	.73	...
28,630	7 D 1	.46	.094	.043	1.05	.138
28,630	8 D 1	.47	.095	.043	1.03	.136
28,630	Ladle	.45	...	.045	.99	...
34,503	9 D 1	.61	.097	.039	.83	.150
34,503	10 D 1	.61	.095	.039	.83	.153
34,503	11 D 1	.61	.094	.037	.84	.150
34,503	12 D 1	.62	.095	.039	.84	.150
34,503	13 D 1	.60	.095	.038	.83	.240
34,503	14 D 1	.60	.094	.039	.82	.328
34,503	15 D 1	.63	.098	.039	.84	.144
34,503	Ladle	.57	.092	.038	.83	.132

It will be noted there was fair agreement between the ladle analyses and the analyses of samples from the rails taken as described, except in the case of carbon in the rails from heat 34,503. The carbon in the rails showed up from .03 to .06 per cent. higher than shown by the ladle sample. In rail samples 13 D1 and 14 D1 the silicon was higher than shown by the ladle test, as these had silicon additions to the molds.

The entire rail-bar of each of the ingots was used for drop tests and transverse tests of the base and was divided into units of one-third rail length each. The pieces cut from each rail and the tests made are shown in table 23.

TABLE 23—TESTS FROM EACH RAIL.

No. 1—2 ft. for transverse test of base.
No. 2—4½ ft. for drop test, head in tension.
No. 3—4½ ft. for drop test, base in tension.
No. 4—2 ft. for transverse test of base.
No. 5—4½ ft. for drop test, head in tension.
No. 6—4½ ft. for drop test, base in tension.
No. 7—2 ft. for transverse test of base.
No. 8—4½ ft. for drop test, head in tension.
No. 9—4½ ft. for drop test, base in tension.

DROP TESTS.

Six drop tests were made of each rail, three with the head in tension and three with the base in tension. The tup was 2,000 lbs., the height of drop was 20 ft., the centers of the supports were three feet apart and the anvil was 20,000 lbs., spring supported. The striking surface of the tup and the bearing surfaces of the supports had radii of 5 in. The deflection in inches was measured after the first blow and was taken as the distance between a 3-ft. straight edge and the part of the anvil where struck by the tup. Gage marks one inch apart were put lengthwise on the side in tension about the middle of the test piece, for a distance of 6 in., and the increase in length of the space which stretched most at failure was taken as the measure of the ductility of the rail. The results of the drop tests are shown in tables 24 to 34 inclusive.

TABLE 24—DROP TESTS, RAIL-BAR 5, HEAT 28,619—PLAIN.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
5 A 2	4.6	2.95	3	30L	Twisted
5 A 5	12.0	...	1	7	Middle
5 A 8	19.4	...	1	8	Middle
5 B 2	27.9	2.50	2	15	Middle
5 B 5	35.4	2.45	4	38	Middle
5 B 8	42.7	2.45	4	45	Middle
5 C 2	51.1	2.50	4	35	Not broken
5 C 5	59.0	2.65	3	35	Base split
5 C 8	66.0	2.60	3	25	Base split
5 D 2	75.5	2.60	5	33	Middle
5 D 5	82.8	2.60	4	32	Not broken
5 D 8	90.2	2.65	5	29	Not broken
Average		2.60	3.3	27.7	
		BASE IN	TENSION		
5 A 3	7.7	2.60	4	34	Not broken
5 A 6	15.0	2.50	4	31	Middle
5 A 9	22.4	2.45	4	26	Near support
5 B 3	30.8	2.40	4	26	Near support
5 B 6	38.4	2.35	5	26	Near support
5 B 9	45.7	2.35	5	30	Middle
5 C 3	54.2	2.45	5	33	Middle
5 C 6	61.5	2.55	5	28	Not broken
5 C 9	69.0	2.50	5	26	Near support
5 D 3	78.4	2.45	5	29	Not broken
5 D 6	85.8	2.55	5	25	Web split
5 D 9	93.2	...	1	7	Middle
Average		2.46	4.3	26.8	
Gen. Av.		2.53	3.8	27.2	

TABLE 25—DROP TESTS, RAIL-BAR 6, HEAT 28,619—2 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Bow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
6 A 2	4.5	2.60	4	32L	Middle
6 A 5	11.8	2.50	3	28L	Middle
6 A 8	19.2	...	1	4	Middle
6 B 2	28.0	2.45	4	33	Base split
6 B 5	35.4	2.50	4	42	Base split
6 B 8	42.7	...	1	8	Middle
6 C 2	50.4	2.60	4	36	Near support
6 C 5	57.7	2.65	3	25	Base split
6 C 8	65.0	2.55	4	29	Middle
6 D 2	74.5	2.60	4	26	Not broken
6 D 5	81.8	2.60	3	30	Base split
6 D 8	89.1	2.60	4	38	Near support
6 D 11	96.4	...	1	2	Middle
Average		2.57	3.1	25.6	
		BASE IN	TENSION		
6 A 3	7.5	2.50	5	22	Not broken
6 A 6	14.8	2.40	4	22	Middle
6 A 9	22.2	2.35	4	32	Middle
6 B 3	31.0	2.35	4	20	Erd Split
6 B 6	38.4	2.45	4	23	Middle
6 B 9	45.7	2.50	5	26	Not broken
6 C 3	53.4	2.45	3	21	Middle
6 C 6	60.7	2.45	5	31	Not broken
6 C 9	68.0	2.45	6	30	
6 D 3	77.5	2.45	4	25	Near support
6 D 6	84.8	2.50	5	22	Middle
6 D 9	92.2	2.45	4	17	
Average		2.44	4.4	24.3	
Gen. Av.		2.50	3.7	25.0	

TABLE 26—DROP TESTS, RAIL-BAR 7, HEAT 28,630—PLAIN.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
7 A 2	4.6	2.30	4	40	Middle
7 A 5	11.8	2.20	2	18	Middle
7 A 8	18.8	2.10	2	17	Middle
7 B 2	27.5	2.20	4	89	Middle
7 B 5	34.6	2.15	3	40	Middle
7 B 8	41.8	2.15	4	35	Middle
7 C 2	49.9	2.05	4	81	Base split
7 C 5	57.0	2.15	5	42	Middle
7 C 8	64.1	2.15	4	44	Middle
7 D 2	73.5	2.15	2	21	Base split
7 D 5	80.6	2.20	5	41	Not broken
7 D 8	87.8	2.15	3	27	Base split
7 D 11	95.0	2.15	4	36	Base split
Average		2.16	3.5	33.2	
		BASE IN	TENSION		
7 A 3	7.5	...	1	6	Middle
7 A 6	14.6	2.15	4	22	Web split
7 A 9	21.8	2.00	4	22	Middle
7 B 3	30.5	2.10	4	26	Middle
7 B 6	37.6	2.10	5	28	End split
7 B 9	44.7	2.10	5	20	Middle
7 C 3	52.8	2.10	5	36	Middle
7 C 6	60.0	2.15	4	28	Middle
7 C 9	67.0	2.10	5	20	Near support
7 D 3	76.5	2.10	5	29	Middle
7 D 6	83.6	2.15	5	22	Middle
7 D 9	90.8	2.15	5	23	Near support
Average		2.11	4.3	23.5	
Gen. Av.		2.13	3.9	28.5	

TABLE 27—DROP TESTS, RAIL-BAR 8, HEAT 28,630—5 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
8 A 2	5.0	2.20	3	27	Middle
8 A 5	12.0	2.20	4	40	Middle
8 A 8	19.1	2.10	2	23	
8 B 2	28.6	2.10	3	26	Base split
8 B 5	35.7	2.10	3	37	Middle
8 B 8	42.7	2.15	3	25	Base split
8 C 2	50.2	2.20	3	30	Near support
8 C 5	57.2	2.20	3	26	Base split
8 C 8	62.3	2.20	4	32	Base split
8 D 2	74.0	2.25	4	28	Not broken
8 D 5	81.1	2.30	3	18	Base split
8 D 8	88.1	2.20	4	27	Middle
8 D 11	95.2	2.15	5	38	Middle
Average		2.18	3.4	29.0	
		BASE IN	TENSION		
8 A 3	7.9	2.15	4	27	Middle
8 A 6	14.9	2.10	3	18L	Middle
8 A 9	22.0	2.10	4	23	Middle
8 B 3	31.5	2.00	4	22	Head broke
8 B 6	38.6	2.00	5	27	Near support
8 B 9	45.6	2.05	4	32	Middle
8 C 3	53.1	2.15	4	27	Near support
8 C 6	60.2	2.15	4	27	Middle
8 C 9	67.2	2.15	5	24	End split
8 D 3	77.0	2.10	5	31	
8 D 6	84.0	2.15	4	25	Near support
8 D 9	91.0	2.15	5	26	Middle
Average		2.10	4.3	25.8	
Gen. Av.		2.14	3.8	27.4	

TABLE 28—DROP TESTS, RAIL-BAR 9, HEAT 34,503—PLAIN.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
9 A 2	5.1	...	1	5	Middle
9 A 5	12.8	...	1	3	Middle
9 A 8	20.5	...	1	5	Middle
9 B 2	30.4	...	1	3	Middle
9 B 5	38.1	...	1	5	Middle
9 B 8	45.8	1.8	2	11	Base split
9 C 2	53.6	1.7	3	15	Middle
9 C 5	61.4	1.7	3	18	Middle
9 C 8	69.1	1.6	3	22	Middle
9 D 2	76.9	...	3	12	Base split
9 D 5	84.6	1.7	3	22	Near support
9 D 8	92.4	1.8	3	14	Base split
Average		1.72	2.1	11.3	
		BASE IN	TENSION		
9 A 3	8.3	...	1	5	Middle
9 A 6	16.0	...	1	4	Middle
9 A 9	25.3	...	1	5	Middle
9 B 3	33.2	1.6	2	11	Middle
9 B 6	41.3	1.6	4	19	Middle
9 B 9	49.0	1.7	3	15	Middle
9 C 3	56.8	1.7	2	7	Near support
9 C 6	64.5	1.7	4	22	Middle
9 C 9	72.3	1.7	4	17	Near support
9 D 3	80.0	1.7	4	18	Middle
9 D 6	87.9	1.7	3	14	Near support
9 D 9	95.5	1.6	4	17	Web split lengthwise
Average		1.67	2.8	12.8	
Gen. Av.		1.70	2.5	13.1	

TABLE 29—DROP TESTS, RAIL-BAR 10, HEAT 34,503—2 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
10 A 2	5.6	1.8	2	11	Middle
10 A 5	13.1	1.8	3	20	Middle
10 A 8	20.5	1.7	2	20	Middle
10 B 2	29.6	1.7	2	16	Middle
10 B 5	37.1	...	1	7	Middle
10 B 8	44.5	1.7	3	21	Middle
10 C 2	51.8	1.7	3	22	Middle
10 C 5	59.3	1.7	3	27	Middle
10 C 8	66.7	1.7	3	24	Middle
10 D 2	74.1	1.7	3	30	Middle
10 D 5	81.5	1.7	3	28	Middle
10 D 8	88.9	1.7	4	31	Middle
Average		1.72	2.7	21.4	
		BASE IN	TENSION		
10 A 3	8.7	1.7	2	10	Middle
10 A 6	16.1	1.7	4	16	Middle
10 A 9	23.5	1.7	3	15	Middle
10 B 3	32.7	1.6	4	18	Middle
10 B 6	40.1	1.7	3	15	Middle
10 B 9	47.5	1.7	2	6	Middle
10 C 3	54.9	...	1	5	Middle
10 C 6	62.3	1.7	2	13	Middle
10 C 9	69.8	1.7	4	15	Middle
10 D 3	77.1	1.7	4	18	Near support
10 D 6	84.6	1.7	4	15	Middle
10 D 9	92.0	1.7	4	19	Middle
Average		1.68	3.1	13.8	
Gen. Av.		1.70	2.9	17.6	

TABLE 30—DROP TESTS, RAIL-BAR 11, HEAT 34,503—5 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
11 A 2	4.7	1.7	3	20	Middle
11 A 5	12.4	1.7	3	19	Middle
11 A 8	20.0	...	1	3	Middle
11 B 2	28.2	1.7	2	13	Middle
11 B 5	35.9	1.7	2	10	Middle
11 B 8	43.6	1.7	3	20	Middle
11 C 2	51.1	1.7	2	10	Middle
11 C 5	58.8	1.7	3	24	Middle
11 C 8	66.5	1.7	2	19	Middle
11 D 2	74.1	1.7	3	21	Middle
11 D 5	81.8	1.7	3	28	Middle
11 D 8	89.5	...	1	9	Middle
Average		1.70	2.3	16.2	
		BASE IN	TENSION		
11 A 3	7.9	1.6	3	17	Middle
11 A 6	15.5	1.7	4	23	Middle
11 A 9	23.2	1.6	3	15	Middle
11 B 3	31.3	1.7	4	22	Middle
11 B 6	39.0	1.7	4	20	Middle
11 B 9	46.6	1.7	2	10	Middle
11 C 3	54.3	1.7	4	22	Middle
11 C 6	62.0	1.7	4	16	Middle
11 C 9	69.6	1.7	4	18	Near support
11 D 3	77.3	1.7	4	17	Near support
11 D 6	85.0	1.7	4	18	Middle
11 D 9	92.8	1.7	4	19	Middle
Average		1.68	3.7	18.1	
Gen. Av.		1.69	3.0	17.2	

TABLE 31—DROP TESTS, RAIL-BAR 12, HEAT 34,503—10 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
12 A 2	5.9	1.7	3	27	Middle
12 A 5	13.5	1.7	2	12	Middle
12 A 8	21.0	1.6	2	10	Middle
12 B 2	28.6	1.7	3	22	Middle
12 B 5	36.2	1.7	2	19	Middle
12 B 8	43.7	1.7	2	19	Middle
12 C 2	51.2	1.7	3	22	Middle
12 C 5	58.8	1.7	3	22	Middle
12 C 8	66.3	1.7	3	25	Near support
12 D 2	73.9	1.7	4	25	Middle
12 D 5	81.5	1.7	5	25	Middle
12 D 8	89.1	1.7	6	16	Twisted
Average		1.69	3.2	20.3	
		BASE IN	TENSION		
12 A 3	9.0	1.7	4	22	Middle
12 A 6	16.5	1.7	4	19	Middle
12 A 9	24.1	1.6	2	14	Middle
12 B 3	31.6	1.7	2	8	Middle
12 B 6	39.2	1.7	2	15	Middle
12 B 9	46.7	1.7	4	19	Middle
12 C 3	54.3	1.7	4	22	Middle
12 C 6	61.9	1.7	5	22	Middle
12 C 9	69.5	1.7	4	22	Middle
12 D 3	77.0	1.7	4	19	Middle
12 D 6	84.6	1.7	3	13	Middle
12 D 9	92.2	1.6	3	15	Near support
Average		1.68	3.4	17.5	
Gen. Av.		1.69	3.3	18.9	

TABLE 32—DROP TESTS, RAIL-BAR 13, HEAT 34,503—.1% SI. ADDITION.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
13 A 2	5.1	...	1	4	Middle
13 A 5	12.8	...	1	5	Middle
13 A 8	20.6	1.6	2	8	Middle
13 B 2	27.1	1.6	3	25	Middle
13 B 5	34.9	1.7	3	21	Middle
13 B 8	42.7	1.7	3	25	Middle
13 C 2	50.5	1.7	3	22	Middle
13 C 5	58.3	1.7	3	25	Middle
13 C 8	66.1	1.6	3	27	Middle
13 D 2	73.9	1.7	2	18	
13 D 5	81.7	1.7	3	24	Middle
13 D 8	89.4	...	3	10	Base split
Average		1.67	2.5	17.8	
		BASE IN	TENSION		
13 A 3	8.2	...	1	3	Middle
13 A 6	16.0	1.7	2	9	Middle
13 A 9	23.8	1.7	4	21	Middle
13 B 3	30.3	1.6	4	20	Near support
13 B 6	38.1	1.7	4	23	Middle
13 B 9	45.9	1.7	5	22	Middle
13 C 3	53.7	1.6	5	19	Middle
13 C 6	61.5	1.7	4	20	Middle
13 C 9	69.3	1.6	4	20	Middle
13 D 3	77.1	1.7	4	17	Near support
13 D 6	84.8	1.7	3	13	Middle
13 D 9	92.7	1.7	4	15	Near support
Average		1.67	3.8	16.8	
Gen. Av.		1.67	3.2	17.3	

TABLE 33—DROP TESTS, RAIL-BAR 14, HEAT 34,503—.2% SI. ADDITION.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
14 A 2	5.4	1.7	3	27	Middle
14 A 5	12.9	..	3	12	Base split
14 A 8	20.5	1.6	3	20	Middle
14 B 2	29.2	..	1	5	Middle
14 B 5	36.8	1.7	3	18	Middle
14 B 8	44.3	1.7	2	15	Near support
14 C 2	51.9	1.7	3	23	Middle
14 C 5	59.3	1.7	2	12	Middle
14 C 8	67.0	1.7	4	30	Middle
14 D 2	74.5	1.7	3	25	Middle
14 D 5	82.1	1.7	2	10	Middle
14 D 8	89.6	..	3	12	Base split
Average		1.69	2.7	17.4	
		BASE IN	TENSION		
14 A 3	8.5	1.7	2	8	Middle
14 A 6	16.0	1.6	3	15	Middle
14 A 9	23.6	1.6	4	20	Middle
14 B 3	32.2	1.7	4	15	Middle
14 B 6	39.9	1.7	4	17	Middle
14 B 9	47.4	1.7	4	15	Middle
14 C 3	55.0	1.7	4	13	Middle
14 C 6	62.5	1.7	4	17	Middle
14 C 9	70.0	1.7	4	17	Middle
14 D 3	77.6	1.7	4	18	Middle
14 D 6	85.1	1.7	3	18	Middle
14 D 9	92.6	1.7	4	17	Middle
Average		1.68	3.8	15.8	
Gen. Av.		1.69	3.3	16.6	

TABLE 34—DROP TESTS, RAIL-BAR 15, HEAT 34,503—PLAIN.

No.	Per Cent. from Top of Ingot.	Deflection, 1st Blow.	No. of Blows.	Elongation, Per Cent.	Where Broken.
		HEAD IN	TENSION		
15 A 2	5.9	..	1	6	Middle
15 A 5	13.4	..	1	3	Middle
15 A 8	21.0	..	1	3	Middle
15 B 2	29.0	..	1	4	Middle
15 B 5	36.5	1.7	2	12	Middle
15 B 8	44.1	1.7	2	14	Middle
15 C 2	51.7	..	2	8	Base split
15 C 5	59.3	..	1	8	Near support
15 C 8	66.7	..	2	9	Base split
15 D 2	74.3	1.7	3	18	Middle
15 D 5	81.8	..	3	11	Base split
15 D 8	89.4	1.7	2	15	Near support
Average		1.70	1.8	9.3	
		BASE IN	TENSION		
15 A 3	8.9	..	1	4	Middle
15 A 6	16.5	..	1	5	Middle
15 A 9	24.1	..	1	3	Middle
15 B 3	32.1	..	1	8	Middle
15 B 6	39.7	1.7	2	12	Near support
15 B 9	47.2	1.7	3	13	Near support
15 C 3	54.7	1.7	2	6	Near support
15 C 6	62.3	1.7	2	7	Near support
15 C 9	69.8	1.6	2	7	Near support
15 D 3	77.4	1.7	3	13	Near support
15 D 6	85.0	1.7	4	17	Near support
15 D 9	92.5	..	1	6	Middle
Average		1.69	1.9	8.4	
Gen. Av.		1.70	1.9	8.9	

The elongation in the drop tests is shown in fig. 11 for rail-bars 5 to 8 inclusive and in Fig. 12 for rail-bars 9 to 15 inclusive, the elongation being represented vertically and the distance from the top of the ingot in per cent. of the total weight being represented horizontally. For each rail-bar one curve represents the results with the head in tension and another curves represents the results with the base in tension. The samples which showed laminations or pipes in the fractures are indicated by an L. A study of these ductility curves is interesting and indicates that the use of aluminum was in general attended with a considerable increase in ductility in the upper part of the rail-bar, where the ductility was low in the plain steel, especially with the higher carbon. The addition of silicon had a similar effect, especially with the .2 per cent. addition. The aluminum additions and the larger addition of silicon were also attended with interior flaws extending downward a considerable distance from the top end of the bar while with plain steel interior laminations as seen in the fractures of the drop-test pieces, were absent or close to the top end. The interior defects or pipes found are shown in table 35. The aluminum and silicon additions it will be remembered were made to the molds while pouring the steel and whether the interior laminations in the rails would occur in the same way if the additions were made to the ladle before pouring the steel into the molds, this investigation does not show.

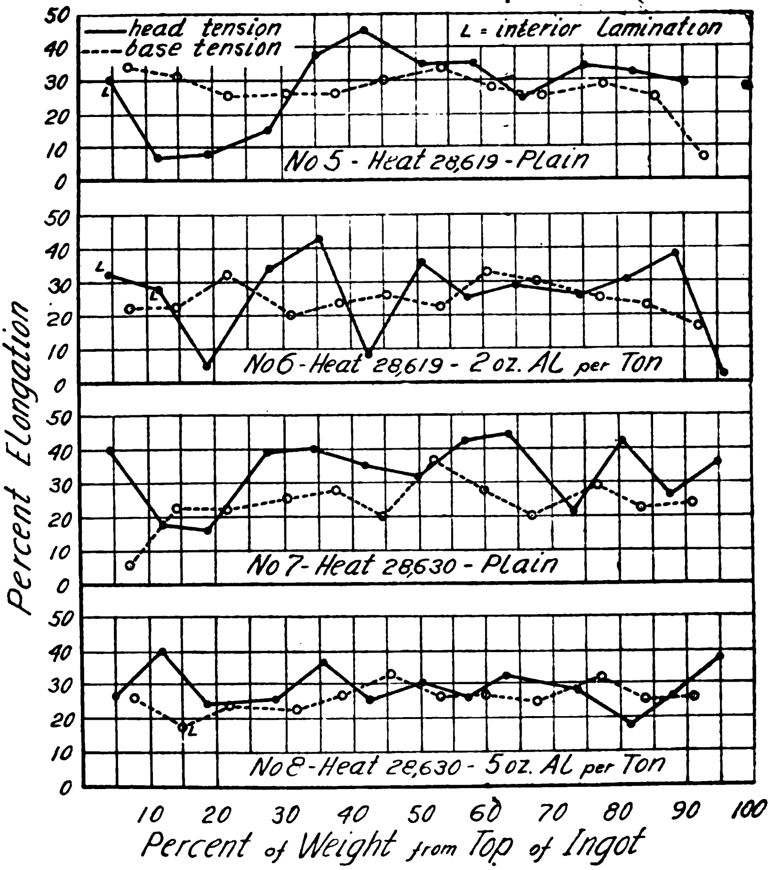


FIG. 11—ELONGATION IN DROP TEST AS RELATED TO DISTANCE FROM TOP OF INGOT, RAIL-BARS 5, 6, 7 AND 8.

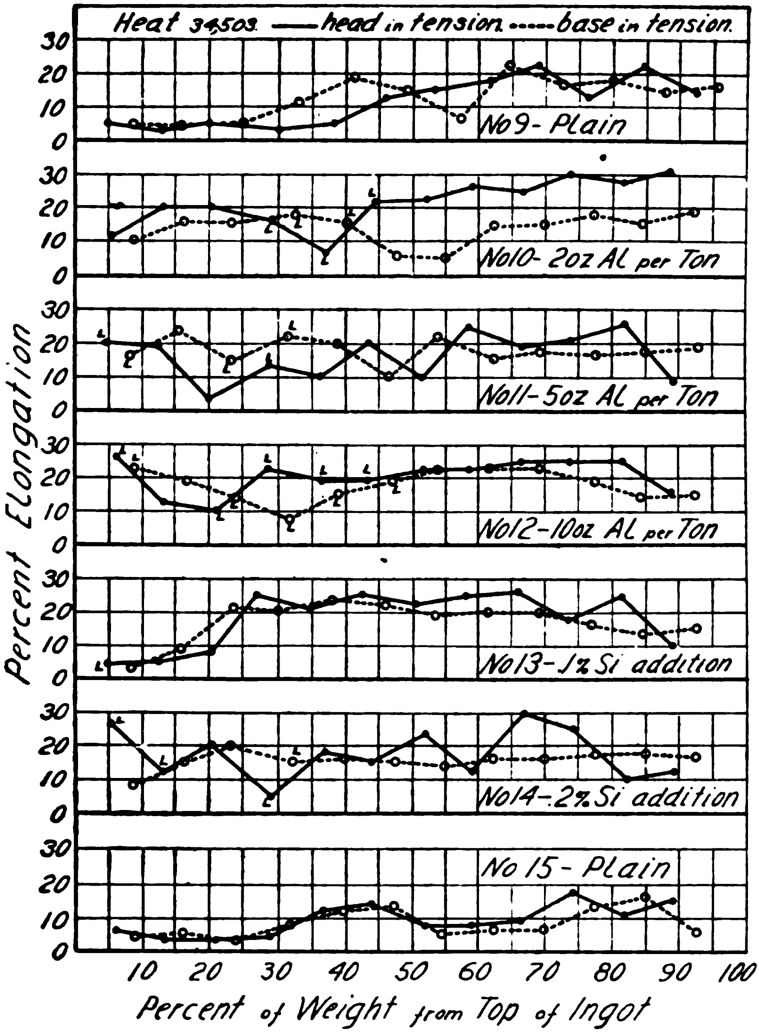


FIG. 12—ELONGATION IN DROP TEST AS RELATED TO DISTANCE FROM TOP OF INGOT, RAIL-BARS 9 TO 15 INCLUSIVE.

TABLE 35—INTERIOR DEFECTS IN RAILS.

Test Piece.	Treatment.	Per Cent. from Top of Ingot.	Defect.
5 A 2	None	4.6	1½" lamination upper part of web.
6 A 2	2 oz. Al.	4.5	Web laminated head to base.
6 A 5	2 oz. Al.	11.8	1½" lamination from head down.
7	None		None found.
8 A 6	5 oz. Al.	14.9	2¼" lamination from head down.
9	None		None found.
10 B 2	2 oz. Al.	29.6	1½" lamination in web.
10 B 3	2 oz. Al.	32.7	1½" lamination in web.
10 B 5	2 oz. Al.	37.1	1½" lamination in web.
10 B 6	2 oz. Al.	40.1	1½" lamination in web.
10 B 8	2 oz. Al.	44.5	Small lamination in web.
11 A 2	5 oz. Al.	4.7	3" lamination in web.
11 A 3	5 oz. Al.	7.9	1½" lamination in web.
11 A 9	5 oz. Al.	23.2	1" lamination upper part of web.
11 B 2	5 oz. Al.	28.2	1" lamination in web.
11 B 3	5 oz. Al.	31.3	1" lamination in web.
12 A 2	10 oz. Al.	5.9	3 small laminations in web.
12 A 3	10 oz. Al.	9.0	2" lamination in web.
12 A 8	10 oz. Al.	21.0	1½" lamination lower part of web.
12 A 9	10 oz. Al.	24.1	1¾" lamination in web.
12 B 2	10 oz. Al.	28.6	1½" lamination in web.
12 B 3	10 oz. Al.	31.6	½" lamination in web.
12 B 5	10 oz. Al.	36.2	1¼" lamination in web.
12 B 6	10 oz. Al.	39.2	2" lamination in web.
12 B 8	10 oz. Al.	43.7	2" lamination in web.
12 B 9	10 oz. Al.	46.7	1" lamination in web.
13 A 2	.1% Si.	5.1	Several ¼" laminations in web.
14 A 2	.2% Si.	5.4	Small lamination head to base.
14 A 5	.2% Si.	12.9	1" lamination upper part of web.
14 B 2	.2% Si.	29.2	1¼" lamination in web.
14 B 3	.2% Si.	32.2	¼" lamination in web.
15	None		None found.

INFLUENCE OF ALUMINUM ON DROP TEST RESULTS.

The average results in the drop tests of the several rail-bars are collected together in table 36, showing the deflection after the first blow from 20 ft., the number of blows that it took to break the rail, and the elongation after breaking. The average head tension, the average base tension and the general average results are given.

TABLE 36—AVERAGE RESULTS IN DROP TESTS.

Rail Bar	Carb.	Treatment	Deflection, 1st blow			Number of blows			Elongation		
			H T	B T	Av.	H T	B T	Av.	H T	B T	Av.
5	.43	None	2.60	2.46	2.53	3.3	4.3	3.8	27.7	26.8	27.2
6	.44	2 oz. Al.	2.57	2.44	2.50	3.1	4.4	3.7	25.6	24.3	25.0
7	.46	None	2.16	2.11	2.13	3.5	4.3	3.9	33.2	23.5	28.5
8	.47	5 oz. Al.	2.18	2.10	2.14	3.4	4.3	3.8	29.0	25.8	27.4
9	.61	None	1.72	1.67	1.70	2.1	2.8	2.5	11.3	12.8	13.1
10	.61	2 oz. Al.	1.72	1.68	1.70	2.7	3.1	2.9	21.4	13.8	17.6
11	.61	5 oz. Al.	1.70	1.68	1.69	2.3	3.7	3.0	16.2	18.1	17.2
12	.62	10 oz. Al.	1.69	1.68	1.69	3.2	3.4	3.3	20.3	17.5	18.9
13	.60	.1% Si.	1.67	1.67	1.67	2.5	3.8	3.2	17.8	16.8	17.3
14	.60	.2% Si.	1.69	1.68	1.69	2.7	3.8	3.3	17.4	15.8	16.6
15	.63	None	1.70	1.69	1.70	1.8	1.9	1.9	9.3	8.4	8.9

The general average elongation and general average number of blows are plotted in Fig. 13 in relation to the amount of aluminum treatment for each of the two grades of steel, the one with about .45 per cent. carbon

and the other with about .61 per cent. carbon. It will be noted that with the .45 per cent. carbon steel the use of aluminum was not attended with an increase in the average ductility of the whole bar. With the 2 oz. treatment the average ductility was somewhat lower than in the plain steel. A study of the diagrams of the individual rail-bars, however, shown in fig. 11 indicates a tendency toward increased ductility in the upper part of the bars, in the aluminum treated steel. With the .61 per cent. carbon steel, the treatment with 2 oz. aluminum per ton of steel was attended

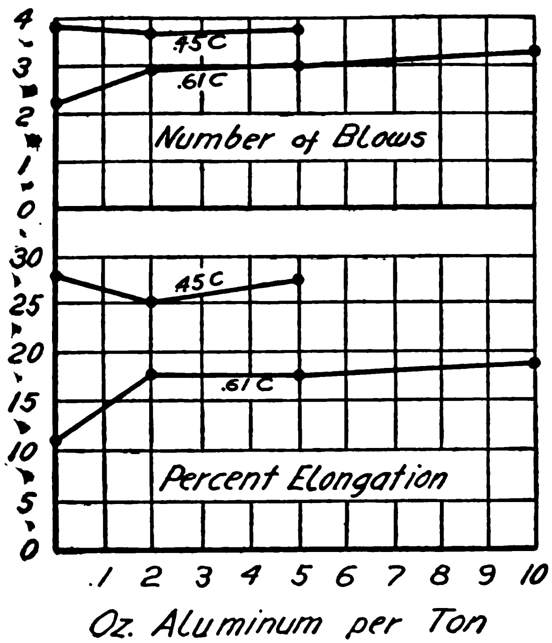


FIG. 13—ELONGATION AND NUMBER OF BLOWS IN DROP TEST AS RELATED TO AMOUNT OF ALUMINUM TREATMENT.

with an increase of the average ductility of the bar, of 60 per cent. With the 5 oz. treatment, there was about the same increase, and with the 10 oz. treatment a little more. A study of the individual diagrams in Fig. 12 shows that the increase was due mostly to the considerable elimination of the brittle zone found in the upper end of the untreated bars, although there was also some improvement along the whole bar.

INFLUENCE OF CARBON ON DUCTILITY.

Incidental to this work we may note the influence the carbon had on reducing the elongation in the drop test measured as already described. From the diagrams in Fig. 13, we may take the elongation of the .45 per cent. carbon steel as 27 per cent. and of the .61 per cent. carbon steel as

17 per cent. An increase in carbon therefore, of .16 per cent. was attended with a decrease in elongation of 10 per cent.; or *roughly, the elongation decreased .6 per cent. for each .01 per cent. increase in carbon, between carbon limits of .45 and .61 per cent.* There were differences in manganese as well as carbon but these seem not to have had a great deal of effect on the ductility, as indicated by a study of table 36, although the deflection was influenced.

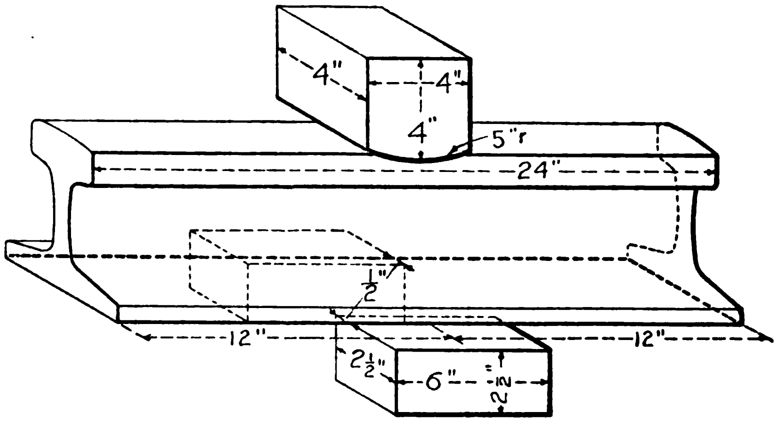


FIG. 14—METHOD OF MAKING TRANSVERSE TEST OF BASE.

TRANSVERSE TESTS OF BASE.

Transverse tests of the base were made of three pieces from each rail, each piece being two feet long. The method of making the test was to support the piece of rail on two supports placed opposite each other near the edges of the flanges under the middle of its length. The supports were six inches long and placed one-half inch in from the sides of the flanges and the load was applied in the test machine to the head of the rail at the middle. The general arrangement is shown in Fig. 14. The load was measured that it took to break the rail. The transverse elongation was measured by putting prick punch marks one inch apart crosswise on the bottom of the base and at the middle of the length of the pieces tested, a multiple punch being used for convenience. The greatest extension after breaking, in any one of the four spaces, was taken as the measure of transverse ductility. The sag of the unbroken flange was measured and was taken as the distance from a straight edge laid on the bottom of the base near the edge of the unbroken flange to the flange where bent most from the straight surface of the base. The results of the transverse tests of the base are shown in tables 37 to 47 inclusive.

TABLE 37—TRANSVERSE TESTS, RAIL-BAR 5, HEAT 28,619—PLAIN.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Elongation, Transverse Per Cent.	Sag of Flange, Inches.
5 A 1	2.4	......	..	..
5 A 4	9.8	146,200	1	.10
5 A 7	17.2	......	0	.08
5 B 1	25.7	187,200	2	.16
5 B 4	33.2	184,600	2	.16
5 B 7	40.5	183,100	2	.14
5 C 1	49.0	213,100	4	.23
5 C 4	56.4	212,000	..	.22
5 C 7	63.8	230,000	4	.30
5 D 1	73.2	201,000	3	.20
5 D 4	80.6	203,600	4	.22
5 D 7	88.0	208,300	4	.24
Average		196,910	2.6	.19

TABLE 38—TRANSVERSE TESTS, RAIL-BAR 6, HEAT 28,619—2 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
6 A 1	2.3	250,000	7	.52
6 A 4	9.7	234,000	6	.42
6 A 7	17.0	191,500	2	.16
6 B 1	25.8	212,700	4	.22
6 B 4	33.2	230,100	6	.35
6 B 7	40.5	218,000	4	.20
6 C 1	48.2	156,400	1	.08
6 C 4	55.5	191,100	3	.18
6 C 7	62.8	220,200	4	.26
6 D 1	72.3	126,200	1	.03
6 D 4	79.6	178,600	2	.14
6 D 7	87.0	139,100	1	.06
Average		195,658	3.4	.22

TABLE 39—TRANSVERSE TESTS, RAIL-BAR 7, HEAT 28,630—PLAIN.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
7 A 1	2.8	156,300	1	.06
7 A 4	9.6	121,200	1	.02
7 A 7	16.7	146,500	1	.02
7 B 1	25.5	158,400	1	.03
7 B 4	32.6	229,100	2	.20
7 B 7	39.7	199,400	2	.10
7 C 1	47.7	......	..	..
7 C 4	54.9	184,000	2	.10
7 C 7	62.0	268,200	6	.34
7 D 1	71.5	232,500	4	.26
7 D 4	78.6	......	..	..
7 D 7	85.7	119,400	0	.01
Average		181,500	2.0	.11

TABLE 40—TRANSVERSE TESTS, RAIL-BAR 8, HEAT 28,630—5 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Load Pounds.	Transverse Elongation, Per Cent.	Sag of Flange. Inches.
8 A 1	2.9	230,400	3	.22
8 A 4	10.0	212,600	3	.14
8 A 7	17.0	200,500	2	.10
8 B 1	26.5	202,100	2	.10
8 B 4	33.6	212,800	3	.14
8 B 7	40.6	214,300	2	.12
8 C 1	48.1	221,800	3	.18
8 C 4	55.2	220,700	3	.16
8 C 7	62.2	244,000	..	.24
8 D 1	72.0	245,800	4	.30
8 D 4	79.0	249,600	5	.28
8 D 7	86.1	142,500	1	.06
Average		216,425	2.8	.17

TABLE 41—TRANSVERSE TESTS, RAIL-BAR 9, HEAT 34,503—PLAIN.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
9 A 1	2.8	116,600	0	.03
9 A 4	10.5	82,000	0	.00
9 A 7	17.1	122,600	0	.02
9 B 1	28.1	152,600	0	.03
9 B 4	35.5	180,500	0	.05
9 B 7	43.5	183,000	1	.10
9 C 1	51.3	177,300	0	.05
9 C 4	59.2	154,000	0	.02
9 C 7	66.8	179,800	1	.07
9 D 1	74.6	187,600	1	.08
9 D 4	82.3	111,900	0	.00
9 D 7	90.1	106,900	0	.00
Average		146,233	0.3	.04

TABLE 42—TRANSVERSE TESTS, RAIL-BAR 10, HEAT 34,503—2 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
10 A 1	3.4	204,700	0	.07
10 A 4	10.9	193,000	2	10
10 A 7	18.3	227,800	1	.14
10 B 1	27.5	241,400	2	.18
10 B 4	34.9	241,500	3	.20
10 B 7	42.3	150,000	0	.03
10 C 1	49.7	180,800	1	.06
10 C 4	57.1	221,400	2	.13
10 C 7	64.5	238,600	3	.22
10 D 1	72.0	206,800	1	.12
10 D 4	79.3	225,700	1	.13
10 D 7	86.8	150,000	0	.05
Average		206,808	1.3	.12

TABLE 43—TRANSVERSE TESTS, RAIL-BAR 11, HEAT 34,503—5 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
11 A 1	2.5	200,100	1	.10
11 A 4	10.1	200,600	1	.09
11 A 7	17.8	216,100	2	.10
11 B 1	25.9	190,500	2	.15
11 B 4	33.6	244,900	3	.18
11 B 7	41.3	257,400	3	.20
11 C 1	48.9	269,300	3	.27
11 C 4	56.5	224,000	2	.13
11 C 7	64.3	164,000	0	.05
11 D 1	71.8	237,000	2	.14
11 D 4	79.6	256,500	3	.25
11 D 7	87.2	241,300	2	.18
Average		225,142	2.0	.15

TABLE 44—TRANSVERSE TESTS, RAIL-BAR 12, HEAT 34,503—10 OZ. AL. PER TON.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
12 A 1	3.6	210,100	0	.08
12 A 4	11.2	252,000	2	.21
12 A 7	18.8	190,700	0	.05
12 B 1	26.3	240,100	2	.17
12 B 4	33.9	246,000	2	.13
12 B 7	41.5	242,400	2	.19
12 C 1	49.0	258,200	3	.26
12 C 4	56.6	243,500	2	.20
12 C 7	64.1	232,800	2	.18
12 D 1	71.7	247,000	3	.15
12 D 4	79.2	222,300	2	.16
12 D 7	86.9	200,600	1	.07
Average		232,142	1.8	.15

TABLE 45—TRANSVERSE TESTS, RAIL-BAR 13, HEAT 34,503—.1% SI. ADDITION.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
13 A 1	2.7	160,600	0	.04
13 A 4	10.6	182,500	1	.06
13 A 7	18.3	183,300	0	.06
13 B 1	24.8	222,100	2	.15
13 B 4	32.6	210,600	1	.10
13 B 7	40.4	230,000	2	.16
13 C 1	49.2	248,000	2	.12
13 C 4	56.0	200,800	1	.09
13 C 7	63.8	157,400	0	.02
13 D 1	71.6	164,600	1	.05
13 D 4	79.4	183,900	1	.06
13 D 7	87.1	211,900	1	.14
Average		196,308	1.0	.09

TABLE 46—TRANSVERSE TESTS, RAIL-BAR 14, HEAT 34,503—.2% SI. ADDITION.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
14 A 1	3.1	164,100	0	.05
14 A 4	10.7	164,300	0	.04
14 A 7	18.3	179,000	0	.03
14 B 1	27.0	219,500	2	.10
14 B 4	34.5	200,800	1	.12
14 B 7	42.1	243,500	2	.12
14 C 1	49.6	229,100	2	.12
14 C 4	57.1	245,000	3	.17
14 C 7	64.8	211,200	2	.11
14 D 1	72.2	241,700	2	.15
14 D 4	79.9	248,000	3	.24
14 D 7	87.4	173,400	1	.04
Average		209,967	1.5	.11

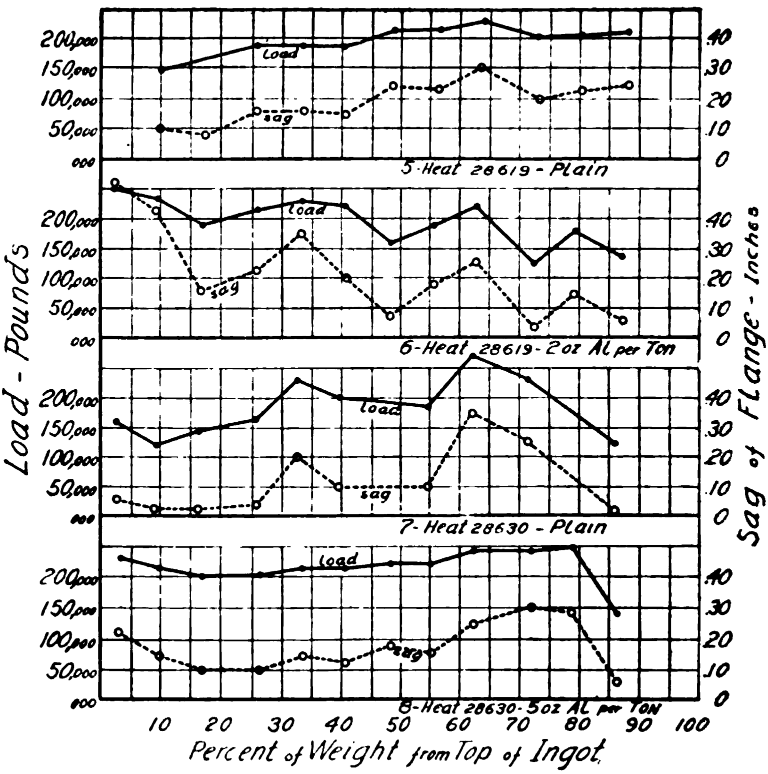


FIG. 15—LOAD AND SAG OF FLANGE IN TRANSVERSE TEST OF BASE AS RELATED TO DISTANCE FROM TOP OF INGOT, RAIL-BARS 5, 6, 7 AND 8.

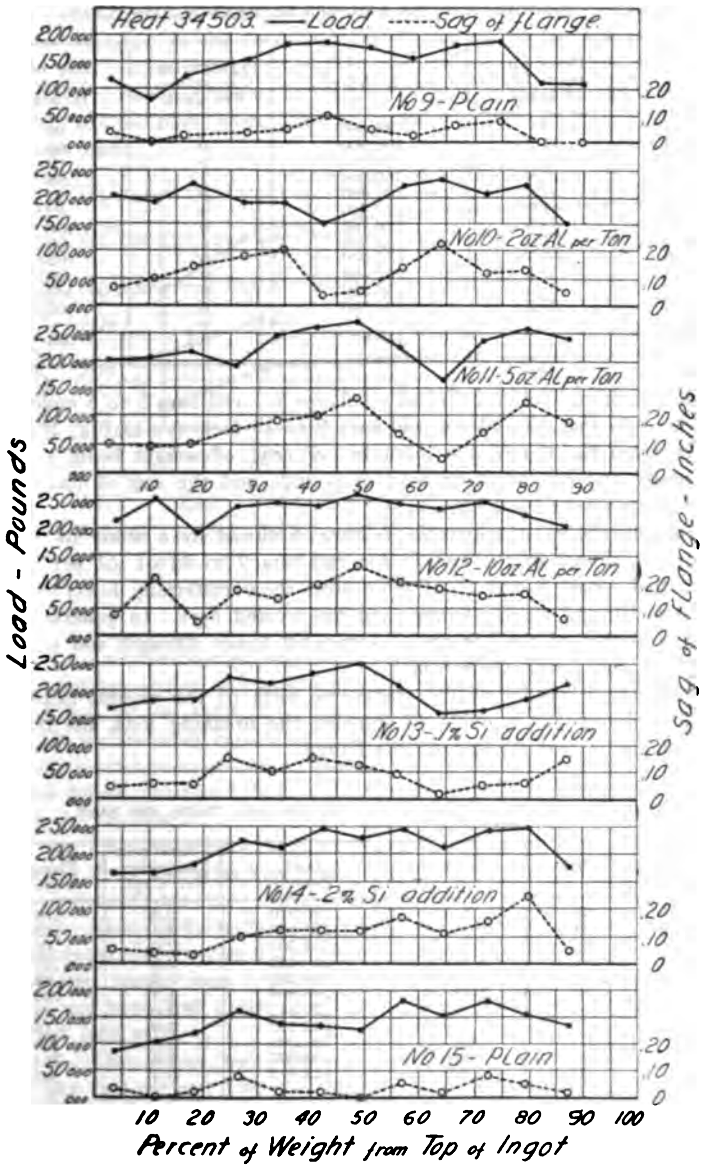


FIG. 16—LOAD AND SAG OF FLANGE IN TRANSVERSE TEST OF BASE AS RELATED TO DISTANCE FROM TOP OF INGOT, RAIL-BARS 9 TO 15 INCLUSIVE.

TABLE 47—TRANSVERSE TESTS, RAIL-BAR 15, HEAT 34,503—PLAIN.

No.	Per Cent. from Top of Ingot.	Load, Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
15 A 1	3.7	84,000	1	.03
15 A 4	11.2	100,900	0	.00
15 A 7	18.8	116,300	0	.02
15 B 1	26.8	159,000	1	.08
15 B 4	34.3	137,600	0	.02
15 B 7	41.9	136,200	0	.02
15 C 1	49.5	126,700	0	.00
15 C 4	57.0	182,800	1	.06
15 C 7	64.5	151,600	0	.02
15 D 1	72.1	180,500	0	.08
15 D 4	79.6	156,300	0	.05
15 D 7	87.2	135,800	0	.02
Average		138,975	0.3	.03

The breaking load and the sag of flange for rail-bars 5 to 8 inclusive are plotted in Fig. 15 and for rail-bars 9 to 15 inclusive in Fig. 16, the distance from the top of the ingot in per cent. of weight being shown horizontally and the breaking load in pounds and the sag of flange in inches being shown vertically.

Probably the most noticeable feature disclosed by a study of these diagrams is shown in the curves for rail-bars 9 to 15 of .61 per cent. carbon steel. Bars 9 and 15 of plain steel show materially lower transverse strength and sag of flange than the treated bars. In general also the upper fourth of the bar shows somewhat lower strength and sag of flange than the lower three-fourths.

The average results of the transverse tests of the several rail-bars are collected together in table 48 showing the breaking load, the transverse elongation and the sag of the flange.

TABLE 48—AVERAGE RESULTS OF TRANSVERSE TESTS OF BASE.

Rail-bar.	Carbon.	Treatment.	Load. Pounds.	Transverse Elongation, Per Cent.	Sag of Flange, Inches.
5	.43	None	196,910	2.6	.19
6	.44	2 oz. Al.	195,658	3.4	.22
7	.46	None	181,500	2.0	.11
8	.47	5 oz. Al.	216,425	2.8	.17
9	.61	None	146,233	0.3	.04
10	.61	2 oz. Al.	206,808	1.3	.12
11	.61	5 oz. Al.	225,142	2.0	.15
12	.62	10 oz. Al.	232,142	1.8	.15
13	.60	.1% Si.	196,308	1.0	.09
14	.60	.2% Si.	209,967	1.5	.11
15	.63	None	138,975	0.3	.03

The results on load and sag of flange, except those for rail-bars 13 and 14, have been plotted in fig. 17 in relation to amount of treatment with aluminum. The amount of treatment in ounces of aluminum per ton of steel is shown horizontally and the load and sag of flange are shown vertically. Separate curves are shown for the .45 and .61 per cent. carbon steels. It will be noted that with .61 per cent. carbon steel the treat-

ment with 2 oz. of aluminum per ton of steel, was attended with considerable increase in the load and sag of flange. With larger treatments there were some further increases. With the .45 per cent. carbon steel there were small increases in load and sag with the aluminum treatments as against the plain steel, but they were not as large as with the higher carbon steel.

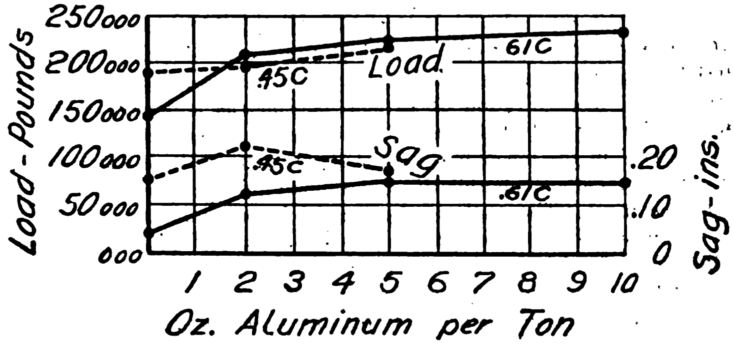


FIG. 17—LOAD AND SAG OF FLANGE IN TRANSVERSE TEST OF BASE AS RELATED TO AMOUNT OF ALUMINUM TREATMENT.

SUMMARY.

1. An investigation was made concerning the influence of aluminum on bessemer ingots and rails when added to the molds while pouring the steel and at the same time some tests were made on the influence of silicon on bessemer rails when added as ferro-silicon to the molds. Four ingots were split open and a chemical survey made of them. Eleven ingots were rolled into 85 or 90 lb. rails and used for drop tests and transverse tests of the base.

2. This work was done at South Chicago, Ill., at the works of the Illinois Steel Co., who kindly furnished all the material and facilities for the investigation.

3. Five ingots were of untreated bessemer steel, eight were treated with aluminum varying from 1 to 10 ounces of aluminum per ton of steel and two ingots were treated with additions of ferro-silicon equivalent to .1 per cent. and .2 per cent. of silicon respectively. These latter were rolled into rails.

4. The ingots used for splitting and chemical survey had about .44 per cent carbon. The plain ingot had a large central cavity or pipe in the upper part of the ingot and a large number of small elongated holes along the sides in the upper part. This ingot also had a raised top. The other three ingots treated respectively with 1 oz., 2 oz. and 5 oz. of aluminum per ton of steel, had somewhat larger pipes but were free from the small elongated holes along the sides. They had flat or sunken tops. Expressed differently, the aluminum treated ingots had larger pipes but contained denser steel around the pipes. One ounce of aluminum per ton

had considerable influence in this direction and the effect increased a little with increase of aluminum.

5. A chemical survey was made of each of the ingots by means of 15 samples from each of five vertical rows from one-half of the section face, making a total of 75 samples from the ingot, minus the samples which could not be taken on account of cavities. On each sample determinations were made of carbon, phosphorus and sulphur and on some of them, of manganese and silicon also.

6. The chemical surveys showed a more even distribution of the material in the aluminum treated ingots. The treated ingots showed less segregation or concentration of carbon, phosphorus and sulphur in the interior and upper part of the ingot. Both plain and treated ingots showed "soft centers" in the lower part of the ingot, that is, there was negative segregation of carbon, phosphorus and sulphur in the interior and lower part of the ingot. The walls of the treated ingots showed a fairly uniform composition throughout their heights. The plain ingot showed a considerable softening or negative segregation in the upper corners. The carbon, phosphorus and sulphur increased in the wall downward of the ingot until the average composition of the steel was reached at about one-third of the height from the top end, after which the wall remained of about uniform composition.

7. Rails were made of steel of two grades of hardness, one of about .45 per cent. carbon rolled into 85 lb. rails and the other of about .61 per cent. carbon rolled into 90 lb. rails. Some were of plain steel, some treated with aluminum varying from 2 oz. to 10 oz. per ton and two were treated with .1 and .2 per cent. respectively of silicon added as ferro-silicon.

8. In the drop tests, the use of aluminum was in general attended with a considerable increase in ductility in the upper part of the bar, where the ductility was low in the plain steel, especially with the higher carbon. The addition of silicon had a similar effect, especially with the .2 per cent. addition. With the .45 per cent. carbon steel, the average ductility of the whole bar was about the same in the aluminum treated as in the plain steel. With the .61 per cent. carbon steel, the average ductility was considerably greater in the aluminum treated bars.

9. The aluminum additions and the larger addition of silicon were attended with interior flaws extending downward a considerable distance (as high as 30 to 45 per cent. of the weight of the ingot) from the top end of the bar, while with plain steel interior laminations as seen in the fractures of the drop test pieces were absent or close to the top end. The aluminum and silicon additions it will be remembered were made to the molds while pouring the steel and whether the interior laminations in the rails would occur in the same way if the additions were made to the ladle before pouring the steel into the molds, this investigation does not show.

10. Incidental to this work, some results were obtained concerning the influence of carbon on ductility as measured in the drop test. The elongation for .45 per cent. carbon averaged about 27 per cent. and for .61 per cent. carbon about 17 per cent. Roughly, the elongation decreased

.6 per cent. for each .01 per cent increase in carbon, between the above carbon limits.

11. Transverse tests of the base were made by supporting pieces of rail 2 ft. long, on two supports placed opposite each other near the edges of the flanges under the middle of the length of the piece tested. The supports were 6 in. long and were placed ½ in. in from the sides of the flanges. The load was applied in the test machine to the head of the rail at the middle.

12. With the .61 per cent. carbon steel, treatment with 2 oz. of aluminum was attended with considerable increase in transverse strength and sag of flange before breaking. With treatments with 5 oz. and 10 oz. of aluminum per ton of steel, there were some further increases. With the .45 per cent. carbon steel, there were small increases in transverse strength and sag of flange with the aluminum treatments as against plain steel.

13. To sum up, ingots treated with aluminum as mold additions, were of more even composition throughout the ingot than plain bessemer steel. There was less positive segregation in the interior and upper part of the ingot but the negative segregation or soft center in the interior and lower parts of the ingot was about the same. There was a softening or negative segregation in the upper part of the wall of the plain ingot while in the aluminum treated ingots, the walls were of fairly even composition throughout the height of the ingot. Aluminum treated ingots had larger and deeper pipes than plain steel but had denser steel around the pipes. Rails of plain steel had a brittle zone in the upper part of the bar as disclosed by the drop test. In the rails of aluminum treated steel this zone was largely eliminated. Rails of plain steel contained their laminations close to the top end of the bar, while in aluminum treated rails, the interior laminations were found a considerable distance from the top end, varying from about 30 to 45 per cent. of the weight of the ingot. In the transverse test of the base, rails of aluminum treated steel showed considerably greater transverse strength of the base and sag of the flange before breaking, than the rails of plain steel, with .61 per cent. carbon and a little greater strength and sag of flange with .45 per cent. carbon.

Appendix H.

SPECIFICATIONS FOR CARBON STEEL RAILS.

1914.

INSPECTION.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made and loaded in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspections shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

MATERIAL.

Material.

3. The material shall be steel made by the Bessemer or Open-Hearth process as provided by the contract.

CHEMICAL REQUIREMENTS.

Chemical Composition.

4. The chemical composition of each heat of the steel from which the rails are rolled, determined as prescribed in Section 6, shall be within the following limits:

Elements	Per Cent. for Bessemer Process		Per Cent. for Open-Hearth Process	
	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive
Carbon	0.40 to 0.50	0.45 to 0.55	0.53 to 0.66	0.62 to 0.75
Phosphorus, not to exceed	0.10	0.10	0.04	0.04
Manganese	0.80 to 1.10	0.80 to 1.10	0.60 to 0.90	0.60 to 0.90
Silicon, not to exceed	0.20	0 20	0.20	0.20

Average Carbon.

5. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

Analyses.

6. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows:

(a) For Bessemer process the manufacturer shall furnish to the inspector, daily, carbon determinations for each heat before the rails are shipped, and two chemical analyses every twenty-four hours representing the average of the elements, carbon, manganese, silicon, phosphorus and sulphur contained in the steel, one for each day and night turn respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than one-eighth inch beneath the surface.

(b) For Open-Hearth process, the makers shall furnish the inspectors with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each heat.

(c) On request of the inspector, the manufacturer shall furnish a portion of the test ingot for check analyses.

PHYSICAL REQUIREMENTS.

Physical Qualities.

7. Tests shall be made to determine:

(a) Ductility or toughness as opposed to brittleness.

(b) Soundness.

Method of Testing.

8. The physical qualities shall be determined by the Drop Test.

Drop Testing Machine.

9. The drop testing machine used shall be the standard of the American Railway Engineering Association.

(a) The tup shall weigh 2,000 lbs., and have a striking face with a radius of five inches.

(b) The anvil block shall weigh 20,000 lbs., and be supported on springs.

(c) The supports for the test pieces shall be spaced three feet between centers and shall be a part of, and firmly secured, to the anvil. The bearing surfaces of the supports shall have a radius of five inches.

Pieces for Drop Test.

10. Drop tests shall be made on pieces of rail not less than four feet and not more than six feet long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks one inch apart for three inches each side of the center of the test piece, for measuring the ductility of the metal.

Temperature of Test Pieces.

11. The temperature of the test pieces shall be between 60 and 100 degrees Fahrenheit.

Height of Drop.

12. The test piece shall ordinarily be placed head upwards on the supports, and be subjected to impact of the tup falling free from the following heights:

For 70-lb. rail ....16 feet
For 80, 85 and 90-lb. rail............................17 feet
For 100-lb. rail ....18 feet

Elongation or Ductility.

13. (a) Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for one inch, or 5 per cent. each for two consecutive inches of the six-inch scale, marked as described in Section 10.

(b) A sufficient number of blows shall be given to determine the complete elongation of the test piece of at least every fifth heat of Bessemer steel, and of one out of every three test pieces of a heat of Open-Hearth steel.

Permanent Set.

14. It is desired that the permanent set after one blow under the drop test shall not exceed that in the following table, and a record shall be made of this information.

Rail			Permanent Set, measured by Middle Ordinate in Inches in a Length of 3 Feet	
Section	Weight per Yard	Moment of Inertia	Bessemer Process	O.-H. Process
A.R.A.-A	100	48.94	1.65	1.45
A.R.A.-B	100	41.30	2.05	1.80
A.R.A.-A	90	38.70	1.90	1.65
A.R.A.-B	90	32.30	2.20	2.00
A.R.A.-A	80	28.80	2.85	2.45
A.R.A.-B	80	25.00	3.15	2.85
A.R.A.-A	70	21.05	3.60	3.10
A.R.A.-B	70	18.60	3.85	3.50

Test to Destruction.

15. The test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound. The words "interior defect," used below, shall be interpreted to mean seams, laminations, cavities or interposed foreign matter made visible by the destruction tests, the saws or the drills.

Bessemer Process Drop Tests.

16. One piece shall be tested from each heat of Bessemer steel.

(a) If the test piece does not break at the first blow and shows the required elongation (Section 13), all of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(b) If the test piece breaks at the first blow, or does not show the required elongation (Section 13), or if the test piece does not break and

shows the required elongation, but when broken shows interior defect, all of the top rails from that heat shall be rejected.

(c) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow, and shows the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(d) If the test piece breaks at the first blow, or does not show the required elongation (Section 13), or if the test piece does not break and shows the required elongation, but when broken shows interior defect, all of the second rails from that heat shall be rejected.

(e) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(f) If the test piece breaks at the first blow, or does not show the required elongation (Section 13), or if the test piece does not break and shows the required elongation, but when broken shows interior defect, all of the remainder of the rails from that heat shall be rejected.

Open-Hearth Process Drop Tests.

17. Test pieces shall be selected from the second, middle and last full ingot of each Open-Hearth heat.

(a) If two of these test pieces do not break at the first blow, and if both show the required elongation (Section 13), all of the rails of the heat shall be accepted, provided that none of the three test pieces when broken show interior defect.

(b) If two of the test pieces break at the first blow, or do not show the required elongation (Section 13), or if any of the three test pieces when broken show interior defect, all of the top rails from that heat shall be rejected.

(c) Second tests shall then be made from three test pieces selected by the inspector from the top end of any second rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow and if both show the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken shows interior defect.

(d) If two of these test pieces break at the first blow, or do not show the required elongation (Section 13), or if any of the three test pieces when broken show interior defect, all of the second rails of the heat shall be rejected.

(e) Third tests shall then be made from three test pieces selected by the inspector from the top end of any third rails of the same heat,

preferably of the same ingots. If two of these test pieces do not break at the first blow, and if both show the required elongation (Section 13), all of the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken shows interior defect.

(f) If two of these test pieces break at the first blow, or do not show the required elongation (Section 13), or if any of the three test pieces when broken show interior defect, all of the remainder of the rails from that heat shall be rejected.

No. 1 Rails.

18. No. 1 classification rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

19. (a) Rails which, by reason of surface imperfections, or for causes mentioned in Section 29 hereof, are not classed as No. 1 rails, will be accepted as No. 2 rails, but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment.

(b) No. 2 rails to the extent of 5 per cent. of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white and shall have two prick punch marks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

DETAILS OF MANUFACTURE.

Quality of Manufacture.

20. The entire process of manufacture shall be in accordance with the best current state of the art.

Bled Ingots.

21. Bled ingots shall not be used.

Discard.

22. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

Lengths.

23. The standard length of rails shall be 33 feet, at a temperature of 60 degrees Fahrenheit. Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 foot from 32 feet to 25 feet. A variation of one-fourth inch from the specified lengths will be allowed, excepting that for 15 per cent. of the order a variation of ⅜ inch from the specified lengths will be allowed. No. 1 rails less than 33 feet long shall be painted green on both ends.

Shrinkage.

24. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will

not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 feet in length and of 100-lb. section, of six and three-fourths inches and one-eighth inch less for each ten lbs. decrease in section.

Cooling.

25. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

Section.

26. The section of rails shall conform as accurately as possible to the template furnished by the Railroad Company. A variation in height of one-sixty-fourth inch less or one-thirty-second inch greater than the specified height, and one-sixteenth inch in width of flange, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the splice bars.

Weight.

27. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding Section. A variation of one-half of 1 per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

Payment.

28. Rails accepted will be paid for according to actual weights.

Straightening.

29. (a) The hot straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rail coming to the straightening presses showing sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet, for A. R. A. type of sections, or 5 inches for A. S. C. E. type of sections, will be at once classed as a No. 2 rail. The distance between the supports of rails in the straightening presses shall not be less than 42 inches. The supports shall have flat surfaces and be out of wind.

(b) Rails heard to snap or check while being straightened shall be at once rejected.

Drilling.

30. Circular holes for joint bolts shall be drilled to conform to the drawing and dimensions furnished by the Railroad Company. A variation of 1-32 inch in excess in size of holes will be allowed.

Finishing.

31. (a) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed

square at the ends, a variation of not more than one-thirty-second inch being allowed; and burrs shall be carefully removed.

(b) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(c) When any finished rail shows interior defects at either end or in a drilled hole the entire rail shall be rejected.

Branding.

32. (a) The name of the manufacturer, the weight and type of rail, and the month and year of manufacture shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered "A," and the succeeding ones "B," "C," "D," etc., consecutively; but in case of a top discard of twenty or more per cent., the letter "A" will be omitted. All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

(b) Open-Hearth rails shall be branded or stamped "O.-H.," in addition to the other marks.

Separate Classes.

33. All classes of rails shall be kept separate from each other.

REPORT OF COMMITTEE I—ON ROADWAY.

W. M. DAWLEY, *Chairman;*
M. J. CORRIGAN,
J. R. W. AMBROSE,
WARD CROSBY,
W. C. CURD,
PAUL DIDIER,
R. C. FALCONER,
S. B. FISHER,
FRANK MERRITT,
L. G. MORPHY,

J. A. SPIELMANN, *Vice-Chairman;*
W. D. PENCE,
F. M. PATTERSON,
L. M. PERKINS,
W. H. PETERSEN,
A. C. PRIME,
H. J. SLIFER,
J. E. WILLOUGHBY,
W. P. WILTSEE,

Committee.

To the Members of the American Railway Engineering Association:

The Committee on Roadway held a general meeting at the Secretary's office, Chicago, November 14, Messrs. Ambrose, Curd, Dawley, Fisher, Patterson, Pence, Slifer and Willoughby being present, to consider the work done by the several Sub-Committees.

The work assigned to the Roadway Committee was divided between three Sub-Committees as follows:

UNIT PRESSURES ALLOWABLE ON ROADBED OF DIFFERENT MATERIALS.

SUB-COMMITTEE A.

S. B. Fisher, Chairman; J. R. W. Ambrose, F. M. Patterson, W. D. Pence, A. C. Prime, H. J. Slifer.

To be able to make any definite recommendations as to allowable unit pressures on roadbed the following points or facts must be determined:

(a) The distribution of the wheel load and impact among the several ties and its variations due to different weights of rail, tie lengths and spacing.

(b) The distribution and variation of this load throughout the ballast from the bottom of the tie to the subgrade for various kinds and depths of ballast.

(c) The ability of subgrade soils of various physical characteristics to withstand the load imposed by the ballast.

(d) A classification of subgrade soils or such minute and detailed description of each kind that they may be readily identified.

(e) A determination, experimentally, of the mechanics of the problem of supporting a load on a soil plane, such as the ballast on the subgrade or an embankment on a level plane.

The objects to be obtained by determining the allowable unit pressures on roadbed are:

(a) A more rational design of track superstructure based upon a definite knowledge of the value and distribution of the forces involved, such for instance as determining the proper length and section of metal ties to replace the present standard-length ties at points where the area of subgrade covered by the ballast is insufficient to support the present or a proposed increase in weight of rolling stock.

(b) The detection and possible elimination of unnecessary and indeterminate stresses in the rail due to variations in the supporting power of the subgrade soil.

(c) The reduction of maintenance charges by a better understanding of the causes of irregular depression of the track superstructure under traffic.

(d) In new locations the engineer knowing the bearing power of the soils encountered may compare a longer line with low maintenance with a shorter line over soils of less bearing power and consequent higher maintenance charges.

The principal benefits to be derived are an increase in safety of operation and a decrease in cost of maintenance.

Sufficient preliminary discussion has been had to determine that nothing further can be done toward defining allowable unit pressures on roadbed till experiments under actual traffic conditions have been made.

A Special Committee has been appointed and arrangements made for a fund sufficient to start the experimental work. (See American Railway Engineering Association Bulletin 161, Association Affairs, page 3.) In case these funds should prove insufficient due to an enlargement of the scope of the investigation, it is the sense of this Committee that a pro-rata assessment on a mileage basis be made against the railways represented in this Association. This levy would at the rate of four-tenths of one cent ($0.004) per mile for each thousand dollars ($1,000) additional required, amount to only $70 for the largest system represented.

The following description by Mr. J. R. W. Ambrose of some interesting experiments which he has conducted is submitted as information:

"After considering the question allotted to this Sub-Committee, viz., 'the allowable unit pressure upon the roadbed,' it is evident that no data can be obtained from existing information, and that anything we do must be in the line of original research and experiment.

"In making this investigation, we naturally run into the question of load distribution through the ballast and likewise the ties and rails, and, therefore, must consider the distribution of the load from the rail to the subsoil.

"My idea is that we first intercept this distribution at the subgrade in order to determine what loading is delivered to the roadbed. Then the first point to determine is the method by which the necessary data can be obtained, and it was with this in view that I performed the following more or less crude experiments:

"The first attempt was made to utilize the principle of the electrical resistance of powdered carbon upon the idea that the resistance varied inversely as the pressure.

"To carry out this idea, a table was constructed 4 ft. square and 1¼ in. in thickness. It has diagonal rows of holes, 2 in. in diameter, ¼-in. deep and spaced 3 in. center to center, beginning with one in the center of the table. In the center of each depression through to the bottom is a ⅛-in. hole (Fig. 1).

"In the bottom of each hole is placed a copper disc connected with a terminal at the outer edge of the table, and the space then filled with

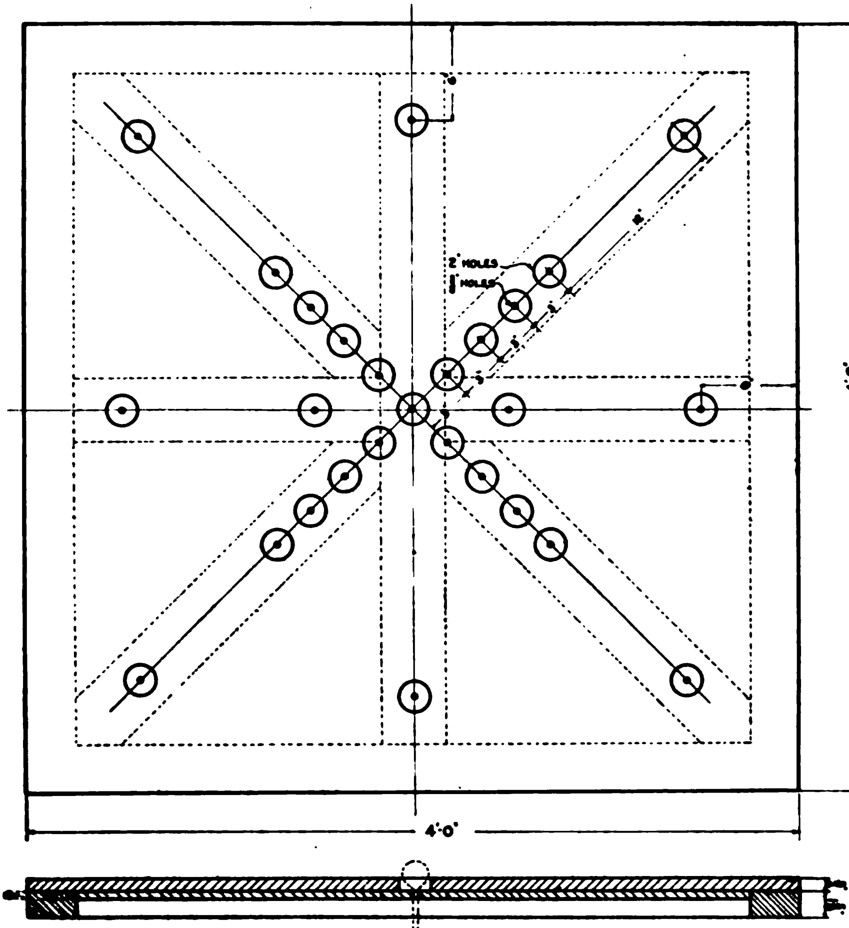


Fig. 1.

powdered electric light carbon mixed with powdered charcoal in proportion of 2 to 1, respectively. On top of this mixture and flush with the top of the table was placed a second copper disc connected to a terminal near the former one at the outer edge of the table.

"The resistance of the carbon in each hole was measured before any loading was applied. Then about 100 lbs. of Ottawa standard sand was

placed on the table in the form of a cone with its center coincident with the center of the table. The resistance in the various pockets was again taken and the difference noted. This was continued under various conditions until it was found that the method was too delicate, although certain information was obtained which showed conclusively that the maximum pressure in the bank was not at its center, and also that at a certain height an arch was formed in the material which transferred the pressure to the side, rather than directly downward, and in trying to destroy this arch by vibrating the table, the value of the resisting quality of the carbon was also destroyed, and therefore this method was abandoned.

"The second method attempted was by using the same table and placing in each of the depressions a small rubber bulb, which in turn was connected by rubber tubing to a glass tube—held in a rack at the side,

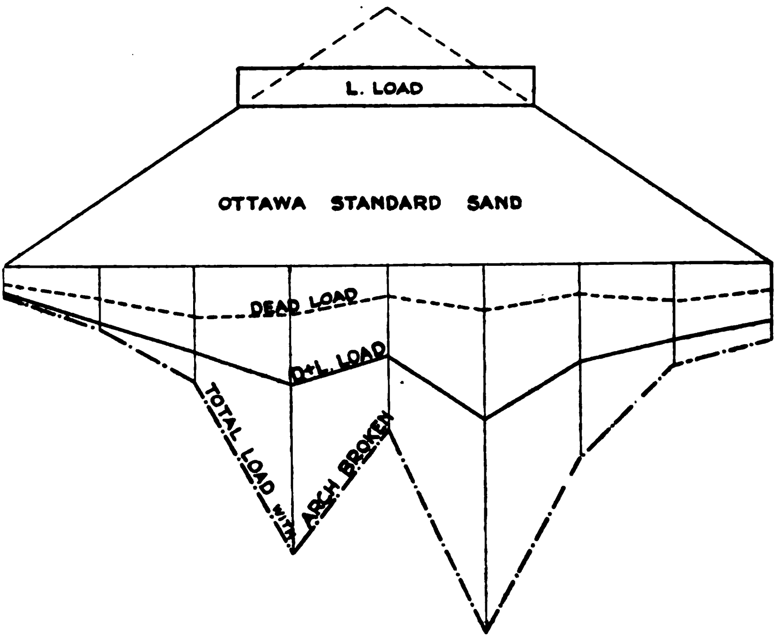


FIG. 2.

and just above the table. Each bulb was filled with water, and the level of the water in all of the glass tubes kept the same before any loading was applied. Then using Ottawa standard sand, a cone was built over the center of the table by applying the sand in 10-lb. lots, and after each lot was applied, a reading in the tube was taken.

"The result of these various loads is shown plotted in Fig. 2. Each of the 9 vertical lines represent a point of application upon a bulb, and also the corresponding glass tube. The dotted line marked dead load represents the result after 100 lbs. of sand had been applied. Then a block of iron weighing 31½ lbs. was applied to the top of the cone, the solid black line showing the result. Then by slightly jarring the table in order to break the arch, we got the result shown in the dot and dash line. It

will be noted that in all instances the pressure at the center is considerably less than that of either side.

"Fig. 3 same as the above, using sand taken from the lake shore.

"Fig. 4 shows the result of an experiment made by building an embankment to scale ½-in. to 1 ft., the embankment being 5 in. high, 6 in. wide on top and having 1½ to 1 slope, which represents 10-ft. bank with a 16-ft. roadway. The bank was built so that the line of tubes ran at right angles to its center line. A small track was built to the same scale and placed on top of the embankment. A small board was fitted with wedge-shaped cleats to represent the points of application of loads from an E-50 engine. Upon these was placed the same iron weight of 31½ lbs., and in Fig. 4 the results obtained will be noted. First—the dotted line showing the load of the embankment. Second—the solid black line showing the load after the weight was applied. Third—the dead load plus the

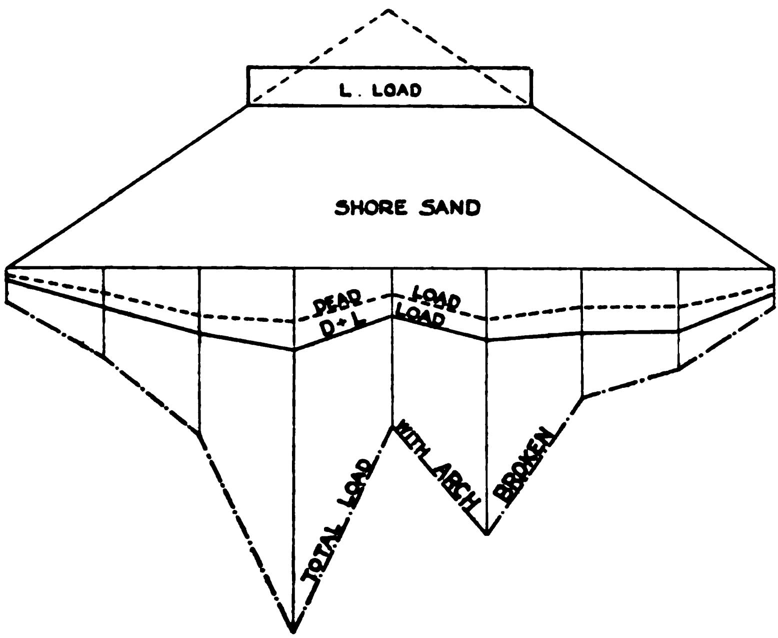


FIG. 3.

live load after the table was slightly jarred, thus breaking down the arch. Fourth—the double dot and dash line which represents the total load after the weight has been alternately taken off and on, with the idea of getting the effect of impact. This was continued until the bank showed evidence of failure by bulging out on either side. The fine solid line indicates the result after the live load was finally removed and the table slightly jarred.

"I think you will agree with me that there is plenty of food for thought, judging from the results shown in Fig. 4, especially when one thinks of how the rail loads seem to affect the roadbed directly underneath them, and not in the center, as one of the members pointed out at our last meeting in Chicago.

"I have one or two other methods in mind which I intend to try, but it probably will be a few weeks before I can give you any result. You, no doubt, have already concluded in your own mind that while the

preceding method seems to show good results for static loads, it would not do at all for recording loads transmitted from a fast-moving train, as the time required for the water or mercury, as the case might be, to return from any given reading to the normal position is quite perceptible."

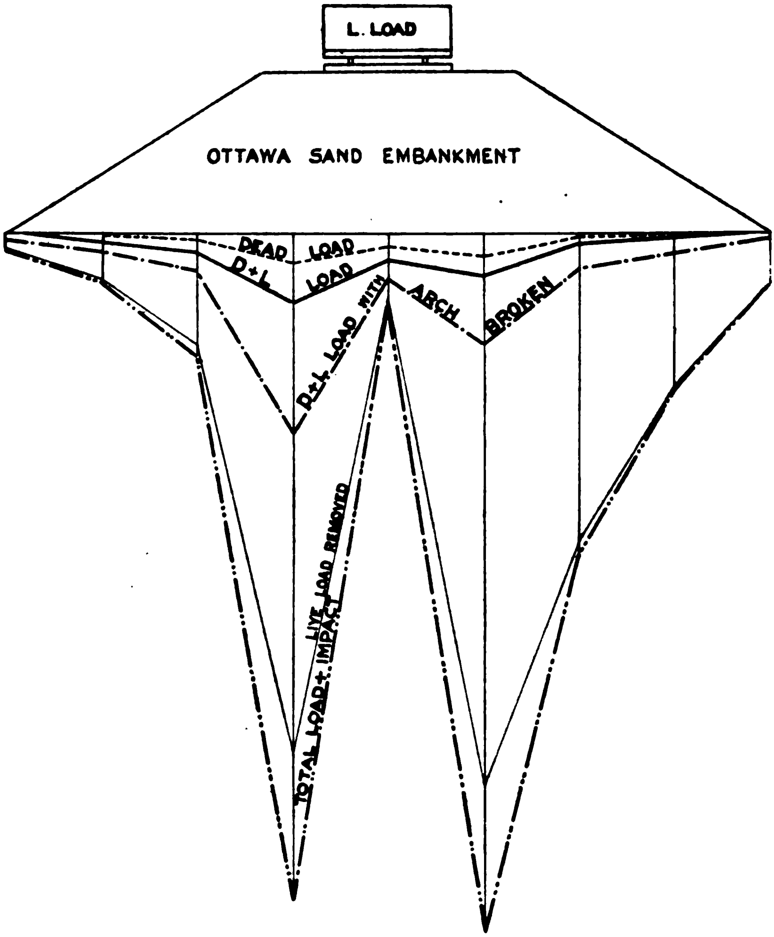


FIG. 4.

In a letter addressed to the Secretary under date of November 9, 1913, Mr. James E. Howard describes some observations made on the Missouri Pacific through the kindness of Mr. J. R. Leighty, Engineer Maintenance of Way, and a few made on the Burlington.

The depression under traffic and subsequent recovery of the embankment and surrounding soil observed, indicating an elastic nature or a wavelike motion of the soil, suggests that the scope of the experimental tests originally contemplated by the Committee may have to be widened. The letter follows herewith:

"Dear Mr. Fritch:—Your letter of the 28th ult. received, also copy of Bulletin No. 142. I have read the report on 'unit pressures allowable on roadbed' with great interest. The remarks of the Committee upon the distinction to be made between data upon deep foundations and impact loading is particularly apropos.

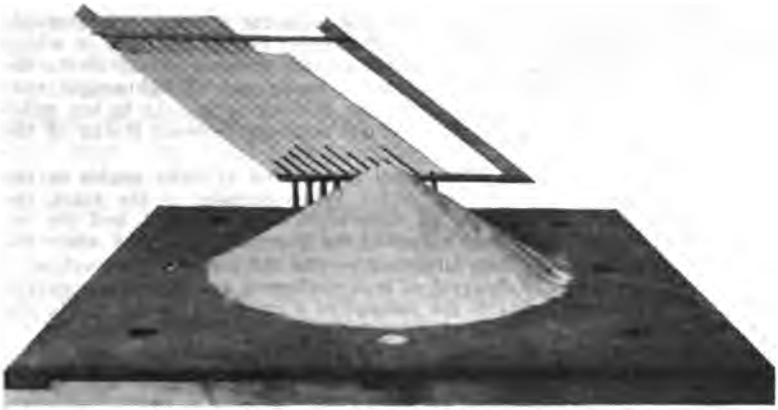


Fig. 5.

"Mr. Prime's method of ascertaining whether the allowable pressure had been exceeded was specially interesting. Experiments and observations to be of greatest value should doubtless be made in such a manner as not to disturb the conditions of the track which is under investigation, and Mr. Prime's method of getting a record from sheet lead accomplishes such a result.

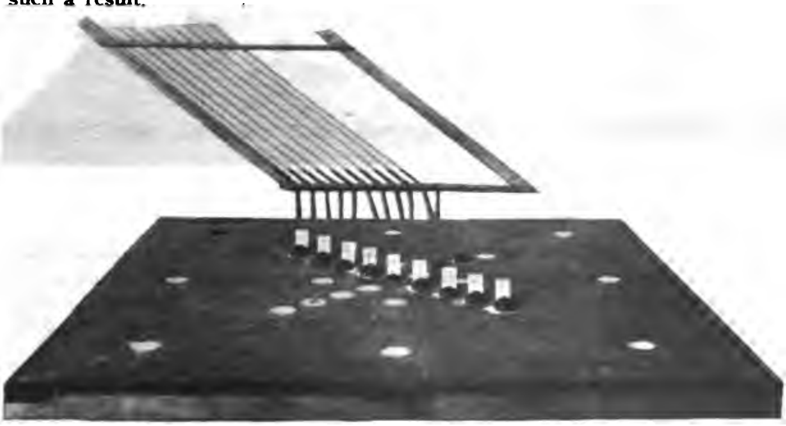


Fig. 6.

"One feature in track maintenance deserves special consideration. It is the exposure and alternate stresses due to variation in load. The difference is very pronounced between repeated stresses and static loading, and this is an obstacle to judging of track conditions in the light of experience in foundation work.

"During the week just passed, I have had opportunity to make a number of observations in the behaving of the surface of the roadbed as affected by the weights of engines and trains. The observations were made on the Missouri Pacific through the kindness of Mr. J. R. Leighty, Engineer Maintenance of Way, a few additional observations having been made on the Burlington.

"The depression of the roadbed and adjacent ground is measurable for at least a distance of 30 ft. from the center line of the track in which the engine and train passes. Within a shorter distance of say 10 ft., the difference in depression between that of heavy and of lightweight cars is noticeable. This is the case of trains moving at say six to ten miles per hour, and at such speeds the partial recovery between trucks of the same car may be noted.

"These cases are where the level was placed at right angles to the direction of the length of the track. When parallel to the track the boundary of the affected zone of depression may be noted, and the reversal in the direction of the slope of the ground ascertained when the engine gets abreast and then advances beyond the place of observation.

"One observation of interest, if it is confirmed, refers to the apparent rebound of the roadbed after the passage of a train at high speed. In the

Fig. 7.

one case observed the train caused first a depression, then immediately after the train got by an elevation above the normal, which subsided in a short time, a few minutes, and came to rest at its normal elevation. Possibly the relative effects of different speeds can be judged of in some such manner as this.

"The rate of travel of wave movements was also noted, that is, an appreciable interval of time is necessary for the roadbed to transmit a wave of depression from the track to places of observation at different distances away.

"These results and others which I expect to make may prove of sufficient interest to bring to the attention of the Association at its coming meeting in March next. I may pass through Chicago within a few days and will call at your office if such is the case.

"Yours very truly,

"(Signed) James E. Howard."

TUNNEL CONSTRUCTION AND VENTILATION.

SUB-COMMITTEE B.

J. E. Willoughby, Chairman; M. J. Corrigan, Ward Crosby, Paul Didier, R. C. Falconer, L. M. Perkins, W. P. Wiltsee.

This subject has been under consideration for a number of years, and on October 10, the following members of your Committee, viz.: M. J. Corrigan, Ward Crosby, J. E. Willoughby and W. P. Wiltsee, met at Bluefield, West Virginia, for examination of the ventilating system (commonly known in the United States as the Churchill-Wentworth System) now installed for the Elkhorn Tunnel, on the Norfolk & Western Railway, and for the Big Bend Tunnel, on the Chesapeake & Ohio Railway.

Two days were devoted to the examination and your Committee had the benefit of the advice of Mr. Chas. C. Wentworth, who, in connection with Mr. Chas. S. Churchill, designed the form of the blowing nozzle, and prepared the plans and specifications for the two plants examined. Your Committee had also information from the operation and maintenance officials who are in charge of the two plants and of the movement of trains using the tunnels.

Your Committee reports as the result of its investigation on tunnel construction:

(1) That the railway tunnels, as ordinarily constructed in the United States, are more economically built by driving first the heading entirely through, but that such method usually requires a greater length of time for completion of the tunnel.

(2) That for material requiring support, the top heading should be usually driven.

(3) That it is economical and expedient to use an electric shovel or an air shovel for the removal of the bench where the section of the tunnel permits the safe operation of the same; and that where the material does not require support, there are advantages in low cost and quick removal of the bench in driving the heading at the subgrade line.

(4) That where the time limit is of value, the heading and bench should be excavated at the same time, the heading being kept 50 ft. in advance of the bench. Where the material of roof is not self-supporting and timbering is to be resorted to, the bench should not be removed until the wall plates are laid and the arch ribs (or centering) safely put up.

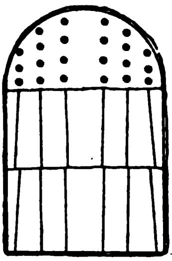
(5) That opposing grades should never meet between the portals of a tunnel, so as to put a summit in the tunnel, and where practicable, the alinement and ascending grades in the tunnel should be in the same direction as the prevailing winds.

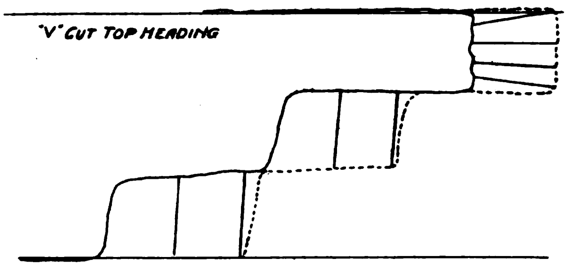
(6) That the attached drawings, Plates I, II and III, are representative of American practice in single-track tunnel construction, where the time limit is of value.

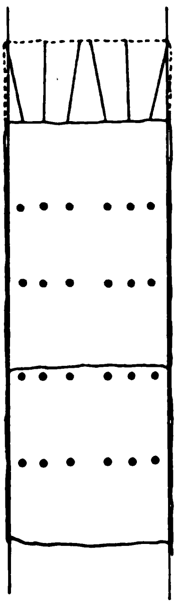
PLATE I.

METHOD OF TUNNEL CONSTRUCTION IN HARD ROCK WITH FEW SEAMS.

SINGLE-TRACK SECTION.







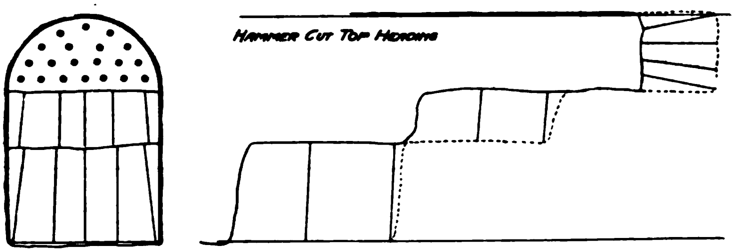
Heading in material of this kind is usually driven by a "V" cut, using from 16 to 22 holes about 8 ft. deep. The holes near the middle of the heading are drilled so as to nearly meet at the end. These holes are the first one shot, then the second row and outside holes last. The arrangement of these holes will vary slightly, according to the way the material breaks.

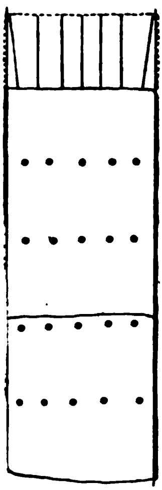
Bench in hard material of this kind is usually taken out in two lifts of almost equal weight. Sub-bench is drilled from 20 to 40 ft. in advance of the bench. From 4 to 8 holes in a row, with about 6 to 8 ft. face, are used in both sub-bench and bench. One or two rows of holes may be used. Center holes are shot first, round and side holes last.

PLATE II.

METHOD OF TUNNEL CONSTRUCTION IN MODERATELY HARD ROCK WITH SEAMS.

SINGLE-TRACK SECTION.





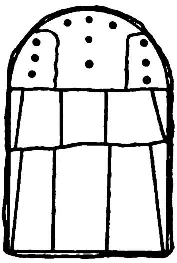
Heading in material of this kind is usually driven by a "hammer cut," using from 14 to 20 holes 6 to 10 ft. deep. The bottom row of holes is inclined at about an angle of 30 degrees. The bottom row is shot first and each row shown in succession. These holes should be arranged to suit the seams in the material.

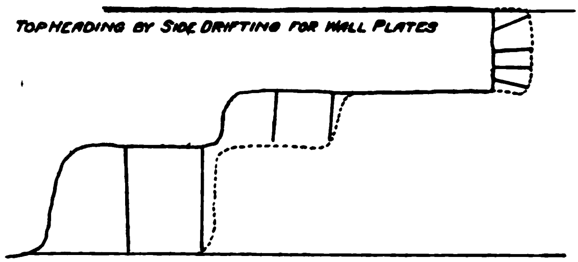
Bench in material of this kind is usually taken out in two lifts, but the sub-bench is not as deep as the bench. Sub-bench is best drilled from 20 to 40 ft. in advance of the bench. From 4 to 6 holes in a row may be used with 6 to 10 ft. face. The bench is sometimes taken out in one lift. Center holes are shot first, round and side holes later.

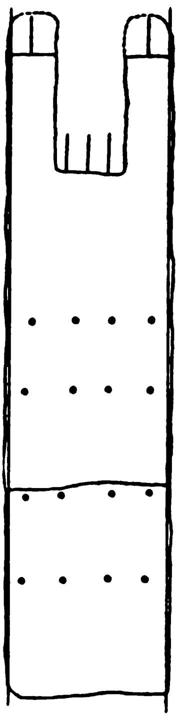
PLATE III.

METHOD OF TUNNEL CONSTRUCTION IN SOFT ROCK OR HARD CLAY.

SINGLE-TRACK SECTION.







This method is only used when material is so soft that heading cannot be driven for full length of timber used for wall plate. Drifts about 4 ft. wide and 6 ft. high are driven for each wall plate, and then core is taken out as timber rings are put in. Three or four holes may be used from 3 to 5 ft. deep in each drift. The amount of shooting necessary depends entirely upon the softness of the material. It can often be picked. The core may be soft enough to pick, or may be shot with from 4 to 8 holes, either drilled from face as shown or from sides of drifts.

Bench in this class of material is shot in one or two lifts. Only very few holes are necessary.

Your Committee, as a result of its investigation, are convinced that tunnels less than half a mile in length when constructed according to adopted section of the Association, and with traffic of less than thirty trains daily, do not usually require artificial ventilation. There are many tunnels in this country more than half a mile in length that carry successfully traffic in excess of thirty trains daily without the aid of artificial ventilation, and while there is in general a direct relation in the need of ventilation to length of tunnel, amount of traffic and size of tunnel section, there are exceptions growing out of local atmospheric conditions and local operating conditions that forbid your Committee from undertaking to fix any definite length or size of section of tunnel as the limit for the installation of artificial ventilation. Your Committee is convinced that the most practicable, effective and economical artificial ventilation for tunnels carrying steam-power traffic is to be obtained by blowing a current of air into one end of the tunnel for the purpose of removing, or of diluting and removing, the smoke and combustion gases at the opposite end. As practiced in America, this way of procuring ventilation partakes of two methods:

(a) To blow the current of air in the direction the train is moving and with sufficient velocity to remove the smoke and combustion gases ahead of the engine;

(b) To blow the current of air against the direction of the train with velocity sufficient to dilute the smoke and combustion gases to such an extent as not to be uncomfortable to the operating crews and to clear the tunnel entirely within the minimum time limit for following trains.

The Elkhorn Tunnel is 3,000 ft. long with a section of 235 sq. ft. The tunnel is for single track, with double track extending from each end of the tunnel. The tunnel is at the top of a long 2 per cent. grade opposed to the heavy coal movement to Norfolk. The grade through the tunnel is 1.4 per cent. The coal trains are handled over the 2 per cent. grade approaching the tunnel with three Mallet engines, one at the head and two in the rear. When the train enters the tunnel one of the rear engines is cut off, and the train carried through the tunnel with one engine at the head and one at the rear. The air is blown into the tunnel from the lower end and in the direction the train is moving up-grade, the locomotives being loaded to their tonnage capacity. The velocity of the current is 1,700 ft. per minute, which is about double the speed of the train. The air current carries the smoke and combustion gases ahead of the engines, making the tunnel clear during the passage of the train. No blowing is done, except when the trains are going up-grade through the tunnel.

This method of blowing is most effective and economical in operation only for single-track tunnels of rather small section, where the locomotives are ordinarily worked to their tonnage capacity and consequently

for trains running at speeds of ten miles per hour or less. This type, has, therefore, a limited use, but it is the desirable type where the conditions are such as permit its installation.

The Big-Bend Tunnel is 6,500 ft. long, with a section of 250 sq. ft. The grade is 0.4 per cent. against the heavy coal movement toward Newport News. This grade is the ruling grade for the operating division. The current of air is blown against the train, and the effect is merely to dilute the smoke and combustion gases by furnishing a supply of fresh air, which current cools and removes the smoke and gases quickly from about the engine cab. After the train has left the tunnel the blowing is continued until the tunnel is clear, which in practicable operation will be within the minimum time interval for following trains.

This method is adapted to tunnels of all sections and for all speeds of trains. The amount of dilution (and therefore the power necessary for its production) is in control of the Engineering Department. These advantages make the Big-Bend Tunnel method the type for general use. Your attention is directed to the table attached, showing points of installation of the type of tunnel ventilation recommended herein.

Your Committee after considering the various types of tunnel ventilation, and from its investigations of the two typical tunnels as above set out, is convinced that effective ventilation for American railway tunnels (exclusive of the type more properly designated as subways) can be obtained only by blowing a current of air into the tunnel during the passage of the trains of sufficient volume to dilute the smoke and combustion gases to such a degree during the passage of the train as to prevent the possibility of partial asphyxiation of train crew and to cool the smoke and gases and remove them entirely from the tunnel section within the minimum time limit for following trains. It regards the Elkhorn type as a special development to be used only where the conditions are favorable.

It is interesting to note that for the first method the small section is most economical, because of less volume of air to be moved, and that the installation of this method of ventilation will enable a railway company to defer enlargement of the tunnel sections of many of the tunnels built long ago, and even delay the necessity of constructing a second-track tunnel in locations where the existing single-track tunnel can be advantageously operated as a gauntlet in a double-track line.

In the report of the Roadway Committee for the year 1912 (see Proceedings, page 398) a record of tunnel ventilation under plans of Chas. S. Churchill and C. C. Wentworth was given as Appendix A. There having been some additional installations, the table has been brought up-to-date and for convenience of reference is presented herewith:

RECORD OF TUNNEL VENTILATION
UNDER PLANS OF CHAS. S. CHURCHILL AND C. C. WENTWORTH.

Location of Tunnel	Date of Installation	Rate of grade	Location of fans	Length of tunnel	Section, sq. ft.	Cubic contents cu. ft.	Cu. ft. of air delivered per minute through tunnel	Remarks
N. & W. Ry. Elkhorn, Coaldale, W. Va.	6-1901	+1.4% E.	Lower end	3000	S.T. 235	705,000	400,000	
C. & O. Ry. Big Bend, E. Hinton, W. Va.	12-1902	½ length +0.4% E.	Upper end	6500	S.T. 250	1,025,000	350,000	
P. R. R. Gallitzin, W. Altoona, Pa.	4-1905	+0.5% W.	Lower end	3600	S.T. 324	1,166,400	502,000	
P. R. R. Washington, D. C., station	12-1907	+0.13% S.	Upper end	Tubes 4050, 1 track; 760, 2 to 6 tracks	280	3,371,800	640,000	2 tubes—530 sq. ft. station end variable
Penna. North and East Rivers, N. Y.	9-1910	Special installation 14 fans of tubes that are for emergency uses. 4135′ to 4357′			Vent 225	....	40,000 to 111,000	
B. & O. R. R. Kingwood, Tunnelton, W. Va.	12-1910	+1.0% E.	Lower end	4138	S.T. 352	1,458,000	600,000	
C. & O. Ry. Lewis, Alleghany, Va.	6-1911	+1.14% W.	Lower end	4026	S.T. 318	1,280,200	508,800	
N. Y. C. Line Weehawken, N. J.	9-1911	+0.25% E.	Lower end	4365	D.T. 469	2,047,200	512,000	144 trains per day
P. R. R. B. & P. Tunnel, Baltimore, Md.	9-1911	+1.32% S.	Upper end	4963	D.T. 432	2,150,000	500,000	193 trains per day
C. G. W. R. R. Winston, Ill.	5-1911	+1.00% E.	Lower end	2500	S.T. 282	705,000	300,000	Only 1 fan installed, 26 trains per day
Va. Ry. Alleghany Tunnel	In progress	+1.22% E.	Lower end	5148	S.T. 369	1,900,000	590,000	
N. P. Ry. Mullan, Mont.	In progress	+2.00% W.	Lower end	3890	S.T. 283	1,108,000	550,000	
N. & W. Ry. Horseshoe	In progress	+0.18% E.	Upper end	3291	S.T. 300	1,000,000	540,000	
N. P. Ry. Stampede, Wash.	In progress	+0.74% E. +0.20% W.	Lower end	9844	S.T. 310	3,150,000	540,000	

ECONOMICS IN ROADWAY LABOR.

SUB-COMMITTEE C.

H. J. Slifer, Chairman; J. A. Spielmann, W. C. Curd, Frank Merritt, L. G. Morphy, W. H. Petersen.

Your Committee has given considerable thought to this subject and we feel we can add little or no information to that which will be submitted by other committees. References to the Proceedings for the year 1913 are as follows:

"Economies in Labor of Signal Maintenance.—Your Committee begs to state that this subject is being considered with reference to the report in 1914."

"Economies in Track Labor.—Your Committee adopted the following preliminary outline for future study, the plan being comprehensive and intended to cover the work of several years." This is followed by voluminous statistical information of great value.

"Economies in Roadway Labor.—Your Committee having agreed with the Track, Signal and Interlocking Committees on a sub-division of the work, reports progress." At the meeting in question, it was agreed that the Roadway Committee would confine its study and recommendations to the question of labor required for construction work only, it being the province of the Track Committee to consider the question of labor required for maintenance work.

Ordinarily, construction work is assigned to contractor's forces and aside from separation of grades (track elevations, subways, etc.), it is seldom necessary to call on the railway engineer to organize labor forces for this class of work.

In view of the fact that all such work is confined to congested terminals, where the magnitude of the work to be accomplished, the time allowed and the interference to traffic are so variable, your Committee feels that any recommendations it might make would be of little or no value.

We do not desire to treat the subject "Economics of Railway Labor" lightly, believing as we do that it is the one important subject before the Association and its individual membership, from a maintenance standpoint. In fact, and with all due deference to the work which has already been done by your several committees, we believe that the subject is one that should have the careful study of a Special Committee, which should be instructed to make its recommendations as to consolidations that might be made to accomplish greater efficiency in inspection and repairs. Some of our members have already recognized the practicability of combining the duties of inspection forces and others have assigned combined crews to miscellaneous repairs and it is believed there is a large field for economical work along these lines.

Your Committee would respectfully request that it be relieved of further consideration of the subject.

CONCLUSIONS.

TUNNEL CONSTRUCTION.

(1) That railway tunnels, as ordinarily constructed in the United States, are more economically built by driving first the heading entirely through, but that such method usually requires a greater length of time for completion of the tunnel;

(2) That for material requiring support, the top heading should be usually driven.

(3) That it is economical and expedient to use an electric shovel or an air-shovel, for the removal of the bench where the section of the tunnel permits the safe operation of the same; and that where the material does not require support there are advantages in low cost and quick removal of the bench in driving the heading at the subgrade line.

(4) That where the time limit is of value, the heading and bench should be excavated at the same time, the heading being kept about 50 ft. in advance of the bench. Where the material of roof is not self-supporting and timbering is to be resorted to, the bench should not be removed until the wall-plates are laid and the arch ribs (or centering) safely put up.

(5) That opposing grades should never meet between the portals of a tunnel, so as to put a summit in the tunnel, and where practicable, the alinement and ascending grades in the tunnel should be in the same direction as the prevailing winds.

(6) That the attached drawings, Plates I, II and III, are representative of American practice in single-track tunnel construction, where the time limit is of value.

TUNNEL VENTILATION.

The most practicable, effective and economical artificial ventilation for tunnels carrying steam-power traffic is to be obtained by blowing a current of air into one end of the tunnel for the purpose of removing, or of diluting and removing, the smoke and combustion gases at the opposite end. As practiced in America, this way of procuring ventilation partakes of two methods:

(a) To blow a current of air in the direction the train is moving and with sufficient velocity to remove the smoke and combustion gases ahead of the engine;

(b) To blow a current of air against the direction of the train with velocity and volume sufficient to dilute the smoke and combustion gases to such an extent as not to be uncomfortable to the operating crews and to clear the tunnel entirely within the minimum time limit for following trains.

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

(1) That subject No. 1 be kept under consideration till the Special Committee on Stresses in Track has made its report.

(2) Submit specifications for the protection of slopes by sodding or otherwise.

(3) Consider the subject of acquiring land for right-of-way from the original survey and option to the final purchase, monumenting and entering on right-of-way maps, submitting necessary forms.

(4) Harmonize specifications heretofore adopted with the Uniform General Contract forms adopted last year.

(5) The construction and maintenance of tracks in tunnels.

(6) The element of cost of earthwork in railway construction.

Respectfully submitted,

COMMITTEE ON ROADWAY.

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

E. A. FRINK, *Chairman;*	W. S. BOUTON, *Vice-Chairman;*
H. AUSTILL, JR.,	P. B. MOTLEY,
F. J. BACHELDER,	A. O. RIDGWAY,
J. E. BARRETT,	I. L. SIMMONS,
F. E. BISSELL,	D. W. SMITH,
E. A. HADLEY,	W. F. STEFFENS,
W. H. HOYT,	H. B. STUART,
H. S. JACOBY,	*Committee.*

To the Members of the American Railway Engineering Association:

The following subjects were assigned for the consideration of your Committee:

(1) Complete report on formulas for use in determining the strength of sheet piling.

(2) Complete report on the use of guard rails for wooden bridges and trestles.

(3) Report on relative economy of repairs and renewals of wooden bridges and trestles.

The Committee was divided into three Sub-Committees, one for each of the subjects assigned, and worked during the year in collecting data. A meeting was held in the Association's rooms at Chicago on January 17, 1914, at which were present H. Austill, Jr., F. J. Bachelder, J. E. Barrett, E. A. Frink, W. H. Hoyt, I. L. Simmons, D. W. Smith, and H. B. Stuart. At this meeting the information and reports furnished by the various Sub-Committees were discussed and the Committee makes the following report and recommendations:

FORMULAS FOR SHEET PILING.

SUB-COMMITTEE A, HENRY S. JACOBY, CHAIRMAN.

This topic has been under consideration before the present year and some experimental investigations were undertaken. The equipment installed at first proved to be inadequate for the purpose. The devices for measuring the pressure of the earth had to be changed and it was hoped that after the preliminary work of the preceding year some satisfactory results might be obtained. As is often the case, however, in experimental research, unexpected difficulties and new problems related to the work have arisen so that no fruitful results can be reported this year. While the outlook is now more favorable, it is impossible to predict how soon the work can be completed.

This topic is closely allied to the investigation now being made by Committee VIII on the principles of design of retaining walls, and the experiments of Committee VIII should throw considerable light on the design of sheet piling. The use of sheet piling is seldom required for wooden bridges or trestles, but is a usual accompaniment of the construction of masonry. Your Committee therefore believes that in order to prevent duplication of experiment, and to serve the best interests of the Association, the report on Formulas for the Use of Sheet Piling should be combined with the report on the principles of Design of Retaining Walls, now being prepared by Committee VIII.

USE OF GUARD RAILS.

SUB-COMMITTEE B, E. A. FRINK, CHAIRMAN.

This subject has been previously investigated by this Committee which submitted certain conclusions at the last annual meeting, all of which conclusions were adopted except the recommendation in conclusion 2, that guard rails be used on all structures over 35 ft. long, which was referred back to the Committee for further consideration and report.

In August, 1913, Circular No. 1, given in Appendix A, was sent to the officers in charge of structures of 329 railroads with a total mileage of 276,544, to which 165 replies were received, covering a total of 170,804 miles of track, a summary of which is also given in Appendix A. 78.9 per cent. of those answering, representing 82.3 per cent. of the railroad mileage answering, recommend guard rails on through bridges. Your Committee believes the protection of trains and the lives of their passengers and crews to be more important than the protection of structures. If, therefore, guard rails are a protection to through bridges, which means that they assist in guiding a derailed train, they will equally be a protection to trains which may be derailed on deck structures, and are therefore desirable. Your Committee therefore recommends the adoption of conclusion 5, given below.

At the annual meeting references were made to the danger of brake-rigging catching in the ends of guard rails. Your Committee believes that this objection can be met by beveling or bending down the ends of guard rails or frog points to the level of the deck, and accordingly recommends the amendment of conclusion 2 as given below.

In changing the wording of conclusion 2 as adopted last year, to eliminate the recommendation to use guard rails on all structures over 35 ft. long, the conclusions were left in such shape as to recommend the use of guard rails. Your Committee has therefore changed the wording of this paragraph to make it consistent with the other recommendations.

ECONOMY OF REPAIRS AND RENEWALS OF TRESTLES.

SUB-COMMITTEE C, W. F. STEFFENS, CHAIRMAN.

Considerable progress has been made in the collection of data regarding existing practice and relative cost of trestle renewals and repairs, but your Committee is not yet in position to formulate conclusions and therefore reports progress.

CONCLUSIONS.

(1) Amend conclusion 2, as adopted at the last annual meeting, to read as follows:

"It is recommended as good practice, in the installation of guard rails, to extend them beyond the ends of the bridges for such distance as is required by local conditions, but that this distance, in any case, be not less than 50 ft.; that guard rails be fully spiked to every tie, and spliced at every joint; that the guard rails be some form of metal section; and that the ends be beveled, bent down, or otherwise protected against direct impact with moving parts of equipment."

(2) Adopt conclusion 5 to read as follows:

"It is recommended as good practice to use inner guard rails on all open-floor and on the outside tracks of all solid-floor bridges and similar structures longer than 20 ft. in main-line tracks, and on similar bridges and structures in branch-line tracks on which the speed of trains is 20 miles per hour or more."

RECOMMENDATIONS FOR NEXT YEAR'S WORK.

Your Committee recommends that the following subjects be assigned for the ensuing year:

(1) Continue report on relative economy of repairs and renewals of wooden bridges and trestles.

(2) Report on design of docks and wharves.

(3) Report on use of lag-screws for fastening guard timbers.

Respectfully submitted,

COMMITTEE ON WOODEN BRIDGES AND TRESTLES.

Appendix A.

GUARD RAILS FOR BRIDGES AND TRESTLES.

CIRCULAR NO. I.

"At the last convention of the American Railway Engineering Association, this Committee was instructed to reconsider its recommendation regarding the use of guard rails on bridges and to obtain further data. To this end you are requested to fill out the following inquiry and return to the undersigned at your earliest convenience.

"Thanking you in advance for the courtesy of a prompt and full reply, I am,

Yours very truly,

E. A. Frink,

Chairman, Committee."

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Committee VII.—Sub-Committee 2.

Guard Rails for Bridges and Trestles.

"Definition: Guard Rail—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track rail, to guide derailed car wheels.

Inquiry.

"1. Does your road use guard rails on all its bridges and trestles?

"2. If not, on what structures are they used?

"3. In your judgment, should guard rails be used?

"(a)—on movable bridges; (b)—on through bridges; (c)—on deck bridges; (d)—on wooden trestles; (e)—on solid floors.

"4. What kind of guard rails do you use?

"5. How far in front of the end of a structure do you extend guard rails?

"6. Are your guard rails full spiked and bolted?

"7. Have you known of instances in which guard rails have prevented damage to bridges?

"8. Give full particulars of each such instance.

"9. Have you known of instances in which guard rails have failed to prevent damage to structures?

"10. Give full particulars of each such instances.

"11. Kindly enclose print of your standard guard rail.

"12. Give any further information or arguments which you think may influence the Committee's action."

SUMMARY OF ANSWERS TO INQUIRY OF CIRCULAR No. 1

	No.	Per Cent	Mil. Rep.	Per Cent
Number of inquiries sent	329	100	276,542	100
" " replies	165	50.2	170,804	51.7
Number of replies	165	100	170,804	100
" using guard rails on all bridges	30	18.2	15,039	8.8
" " " " " some "	117	71.0	151,348	88.6
" " " " " no "	18	10.9	4,417	2.5
" advising use on all bridges	49	29.7	54,523	31.9
" " " " movable bridges	115	69.8	132,912	77.8
" " " " through "	130	78.9	140,556	82.3
" " " " deck "	108	65.5	95,658	56.0
" " " " timber trestles	94	57.0	73,830	43.2
" " " " solid-floor structures	60	36.4	59,460	34.8
" not advising use on all bridges	5	3.0	3,367	1.9
" " " " " movable bridges	16	9.7	15,269	8.9
" " " " " through "	7	4.2	4,726	2.7
" " " " " deck "	13	7.9	5,977	3.5
" " " " " timber trestles	13	7.9	6,093	3.6
" " " " " solid-floor structures	38	23.0	22,603	13.2
" reporting cases where guard rail prevented damage	84	50.9	103,317	60.5
" reporting cases where guard failed	33	21.3	60,156	35.2

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

A. J. HIMES, *Chairman;*
J. A. BOHLAND.
A. W. BUEL.
A. W. CARPENTER.
CHARLES CHANDLER.
C. L. CRANDALL.
J. E. CRAWFORD.
F. O. DUFOUR.
W. R. EDWARDS.

O. E. SELBY, *Vice-Chairman;*
WILLIAM MICHEL.
W. H. MOORE.
ALBERT REICHMANN.
C. E. SMITH.
I. F. STERN.
G. E. TEBBETTS.
F. E. TURNEAURE.
L. F. VAN HAGAN.

Committee.

To the Members of the American Railway Engineering Association:

The subjects assigned to your Committee for investigation during the past year are:

(1) Report on the methods of protection of iron and steel structures against corrosion.

(2) Study the design of built-up columns, co-operating with other investigators and committees of other societies.

(3) Report on design and length of turntables.

(4) Report on the relative economy of various types of movable bridges for varying lengths of span.

In addition to these subjects, there remained from the preceding year unfinished business as follows:

(5) Investigation of secondary stresses and impact.

(6) Adaptation of designs of movable bridges to signal and interlocking appliances required.

(7) Specifications for phosphor bronze.

(8) Bridge clearance diagram.

(9) Revision of the Manual: Specifications for elastic limit; revision of paragraph 23 of "Instructions for the Inspection of the Fabrication of Steel Bridges."

Because of the large number of members of the Committee and their wide geographical distribution and also the considerable volume of work in hand, the several subjects were assigned to sub-committees as follows:

Sub-Committee A, Subject (1):

G. E. Tebbetts, Chairman;
J. A. Bohland,
Charles Chandler,
F. O. Dufour,
W. R. Edwards,
C. E. Smith,
L. F. Van Hagan.

Sub-Committee B, Subject (2):
W. H. Moore, Chairman;
A. W. Carpenter,
C. L. Crandall,
J. E. Crawford,
C. E. Smith,
I. F. Stern.

Sub-Committee C, Subject (3):
O. E. Selby, Chairman;
Charles Chandler,
J. E. Crawford,
W. R. Edwards,
Wm. Michel,
Albert Reichmann,
C. E. Smith.

Sub-Committee D, Subject (4):
Albert Reichmann, Chairman;
J. A. Bohland,
A. W. Buel,
A. W. Carpenter,
G. E. Tebbetts,
F. E. Turneaure.

Sub-Committee E, Subject (5):
F. E. Turneaure, Chairman;
C. L. Crandall,
F. O. Dufour,
Albert Reichmann.

Sub-Committee F, Subject (6):
O. E. Selby, Chairman;
C. E. Smith.

Sub-Committee G, Subject (7):
O. E. Selby, Chairman;
F. O. Dufour.

Sub-Committee H, Subject (8):
C. L. Crandall, Chairman;
A. W. Buel,
W. R. Edwards,
Wm. Michel,
W. H. Moore,
I. F. Stern,
L. F. Van Hagan.

REVISION OF THE MANUAL.

Sub-Committee I, Subject (9). (a) Specifications for Elastic Limit:
A. W. Carpenter, Chairman;
F. O. Dufour,
Albert Reichmann,
O. E. Selby,
L. F. Van Hagan.

Sub-Committee I, Subject (9). (b) Revision of paragraph 23 of "Instructions for the Inspection of the Fabrication of Steel Bridges."
Albert Reichmann.

The investigation of these several subjects has been carried on largely by correspondence, but several meetings of Sub-Committees have been held. On October 17 a meeting of the whole Committee was held at Buffalo, N. Y. The following members attended: A. J. Himes, Chairman; O. E. Selby, Vice-Chairman; C. L. Crandall, F. O. Dufour, W. R. Edwards, Albert Reichmann, G. E. Tebbetts and F. E. Turneaure

On January 20 a meeting of the whole Committee was held at the U. S. Bureau of Standards, Washington, D. C. The following members attended: A. J. Himes, Chairman; J. A. Bohland, Charles Chandler, C. L. Crandall, W. R. Edwards and W. H. Moore. William Michel was represented by his assistant, Mr. Eastman, and the American Society of Civil Engineers' Special Committee on Steel Columns and Struts was represented by its Chairman, A. L. Bowman. The location for the meeting was selected in order that the Committee might witness the first of the column tests being made by the Bureau, under the direction of the Committee.

Your Committee submits a final report on "Methods of Protection of Iron and Steel Structures against Corrosion" in Appendix A.

This report is submitted as information and without recommendation.

The "Study of the Design of Built-up Columns" has made but little progress during the year. Considerable delay was encountered in securing material for the columns in the first series of tests. Some of these tests are now being made and a progress report is presented in Appendix B.

Progress is being made on the subject of "Design and Length of Turntables."

It is recommended that this subject be continued during the coming year.

"The Relative Economy of Various Types of Movable Bridges for Varying Lengths of Span" is a subject that covers such a diversity of conditions as not to admit of the formulation of principles of general application. It is therefore recommended that the Committee be relieved from its consideration for the present.

The "Investigation of Secondary Stresses and Impact" is reported on in Appendix C.

This material is submitted as a progress report. The subject should be re-assigned for further study.

The "Adaptation of Designs of Movable Bridges to Signal and Interlocking Appliances Required" has been subject of careful study by a joint Sub-Committee representing Committees II and III of the Railway Signal Association, and Committees X and XV of the American Railway Engineering Association. The final report is presented in Appendix D, and is recommended for adoption and publication in the Manual.

A "Specification for Phosphor Bronze" has received some discussion during the year and considerable information has been received. However, it is not in shape for presentation to the Association at this time.

The "Bridge Clearance Diagram" has been the subject of an exhaustive study. Any changes in the present diagram will have such far-reaching importance that no change should be made hastily and the work of the Committee has thus far consisted in the compilation of prevailing opinions and practices on the various roads. This information is shown in Appendix E, and is submitted as a progress report. It is recommended that the investigation be continued.

(a) The Committee has no report to make upon the "Specifications for the Elastic Limit."

(b) Paragraph 23 of "Instructions for the Inspection of the Fabrication of Steel Bridges," page 88, of Volume 14 of the Proceedings, has been amended to read as follows:

"23. Have the assembling of trusses and girder spans required by the specifications carefully done and in any case insure the accuracy of field connections. If a large number of duplicate parts are to be made, the number of parts to be assembled should be governed by the workmanship. If errors are found, a sufficient number of parts should be assembled to make it reasonably certain that such errors have been eliminated."

This paragraph is recommended for adoption and publication in the Manual.

The following additional clauses for the inspection of the fabrication of steel bridges are submitted for adoption and publication in the Manual:

"1. Check every finished member against the drawings for its general dimensions and for the section of each piece of material forming a component part of the member.

"2. Attend the weighing of material whenever practicable, especially that purchased on weight basis. Check the accuracy of the scales with test weights or by other sufficient means."

CONCLUSIONS.

Your Committee recommends that the following action be taken on the report submitted herewith:

(1) That the report on methods of protection of iron and steel structures against corrosion be received as information.

(2) That the report on secondary stresses be received as information.

(3) That the report on requirements for the protection of traffic at movable bridges be adopted and published in the Manual.

(4) That the report on bridge clearance diagram be received as information.

(5) That revised paragraph 23 of "Instructions for the Inspection of the Fabrication of Steel Bridges" be adopted and published in the Manual. That the two additional clauses relating to the same subject be adopted and published in the Manual.

Respectfully submitted,

COMMITTEE ON IRON AND STEEL STRUCTURES.

Appendix A.

METHODS OF PROTECTION OF IRON AND STEEL STRUCTURES AGAINST CORROSION.

PIGMENTS.

Pigments may, in respect to their action upon steel in water, be divided into three classes, each of which merge into the next by easy steps, so that the line of demarcation is difficult to ascertain. These classes are the "inhibitive," the "neutral" (inerts or indeterminate), and the "stimulative." The "inhibitive" pigments retard rust, the "stimulative" hasten the corrosion, while the "inerts" are an intermediate class which apparently leaves the material in much the same condition as it was originally, the only protective action being that of a covering pure and simple. It should be noted that the chemical composition of the metal influences the action of the pigment and may reduce the protective action of weak inhibitors.

Pigments may further be divided according to their ability to exclude and to shed moisture. There is a distinction between the two classes mentioned. A pigment may exclude the moisture and still be of such a surface character as to allow it to stand upon the surface until it evaporates or is absorbed; or a pigment may have such surface characteristics that the moisture will run off. A "shedding" pigment may be a greater absorber of moisture than an "excluder" and still be a superior protection, according to the conditions of location.

Strong inhibitors may be weak "excluders" or "shedders," while "stimulators" may have high qualities as "excluders" or "shedders."

Pigments may have different coefficients of expansion and "drying" and different modulii of elasticity. In cases where great differences obtain in any or all of these properties, the surface may "alligator" or crack. In some cases the finishing coat has "alligatored" along the priming coat, which was of a different color, and this shows through. The liability of some of the best "inhibitors" to crack or alligator is so great as to preclude their use in many cases.

The chemical processes by which the pigments are prepared exert a marked influence in the action of the pigment on the metal. For example, Prussian blue may be either inhibitive, neutral or stimulative. according to the process of manufacture. This condition of affairs probably serves as a basis for discussion where one person condemns and another lauds a certain pigment used in different cases under the same conditions. Failure occurred in one case, and fair satisfaction was given in the other.

The consideration of the conditions of exposure are also important in the selection of a pigment. The chemical composition of the pigment

may be affected by either heat, light, moisture or gases, so that it would fail, whereas if one or more of these deteriorating influences was absent, good service would be obtained.

The vehicle is as important as the base. While the vehicle may, on account of porosity or other features, be objectionable, yet the addition of the pigment will, by reason of the filling of the voids, produce a successful protective coating.

Investigators have concluded that the size of the pigment particles is important and that the law of minimum voids holds true in the preparation of protective coatings, as well as in concrete. Therefore, either various proportions of the same pigment, which have different degrees of fineness, or the mixing of pigments of different degrees of fineness, would seem to be advisable. The spreading value of a pigment is an important consideration, secondary, of course, to its protective action, but still influencing it. Too high a spreading quality causes films of paint too thin to withstand the actions of the deteriorating influences.

Investigators appear to have come to the conclusion that bituminous coatings protect metal better than any other, but that the acion of sunlight readily destroys their life and, hence, the value, and that, therefore, they are practically of no value as a protective agent where subjected to the action of light.

From the preceding it appears that:

(1) Priming coats should always be inhibitors, whether or not they are excluders or shedders.

(2) Finishing coats should be excluders or shedders; shedders, preferably, whether or not they are inhibitors, neutrals or stimulators.

(3) Care must be taken to consider the deteriorating influence and determine the chemical requirements of the pigment accordingly.

(4) In cases where a pigment appears in more than one class, care should be taken to determine its process of manufacture before using it as a priming coat.

(5) That the best results will probably be obtained by using an "inhibitive" and "excluder" or "shedder" pigment for both priming and finishing coats, due consideration being paid to (3).

Table 1 gives the classes to which commonly-used pigments belong:

TABLE 1—CLASSIFICATION OF PIGMENTS (CUSHMAN).

Inhibitors	Indeterminates	Stimulators
Zinc and Lead Chromate	White Lead (Quick Process, Basis Carbonate)	Lamp-black
Zinc Oxide	Sublimed White Lead (Basic Sulphate)	Precipitated Barium Sulphate (Blanc Fixe)
Zinc Chromate	Sublimed Blue Lead	Ochre
Zinc and Barium Chromate	Lithopone	Bright Red Oxide
Zinc Lead White	Orange Mineral (American Red Lead)	Carbon Black

TABLE 1, Continued—CLASSIFICATION OF PIGMENTS (CUSHMAN).

Inhibitors	Indeterminates	Stimulators
Prussian Blue (inhibitive)	Litharge	Graphite No. 2
Chrome Green (Blue tone)	Venetian Red	Barium Sulphate (Barytes)
White Lead (Dutch process)	Prince's Metallic Brown	Graphite No. 1
Ultramarine Blue	Calcium Carbonate (Whiting)	Prussian Blue (Stimulative)
Willow Charcoal	Calcium Carbonate (Precipitated)	Linseed Oil
	Calcium Sulphate	
	China Clay	
	Asbestine	
	American Vermilion	
	Medium Chrome Yellow	

From this it is seen that the carbon and graphite paints should not be used as primers, that the zinc and zinc lead pigments are good primers, while the lead basis may belong to either class, according to their method of manufacture.

Table 2 gives the relative moisture value of pigments (Cushman):

TABLE 2—MOISTURE EXPERIMENTS.

Experiments Given Express Gain in Weight, e. g., Water Absorbed.

Rank	Pigment	Relative Units Absorbed in 7 Days
1	Iron Oxides (with 2 per cent. Zinc Chromate and 2 per cent. Gum)..	0.032
2	White Lead, D. D....................	0.040
3	White Lead and Zinc Oxide..........	0.043
4	China Clay	0.044
5	Whiting	0.044
6	Zinc Oxide, Barytes and Blanc Fixe.	0.048
7	Zinc Lead White.....................	0.049
8	Red Lead	0.049
9	Basic Sulphate—White Lead.........	0.049
10	Zinc Oxide and Whiting.............	0.060
11	Zinc Chromate	0.064
12	Barytes and Zinc Oxide.............	0.064
13	Zinc Oxide	0.065
14	Calcium Sulphate	0.066
15	American Vermilion	0.069
16	White Lead, Barytes and Blanc Fixe.	0.074
17	Barytes	0.074
18	Willow Charcoal	0.077
19	Lithopone	0.083
20	Carbon Black	0.084
21	Lead and Zinc Chromate............	0.086
22	Chinese Blue (Stimulative)...........	0.092
23	Venetian Red	0.093
24	Natural Graphite	0.104
25	Medium Chrome Yellow..............	0.106
26	Bright Red Oxide	0.116
27	Barium and Zinc Chromate..........	0.116
28	Ultramarine	0.119
29	Prussian Blue (Inhibitive)..........	0.125
30	Raw Linseed Oil.....................	0.143
31	Lamp-black	0.199
32	Blanc Fixe	0.219

It shows that some of the best inhibitors are in the lowest "excluder" coefficient, and vice versa—although some of the best inhibitors are the best excluders.

It is of particular interest to note that raw linseed oil alone stands 30 in a list of 32, being one of the worst excluders. This alone should be sufficient to remove it for the priming coatings and all experiments appear to show that, as a primer coating, it is also one of the greatest stimulators.

PRESERVATIVE COATINGS FOR IRON AND STEEL.

As the American Society for Testing Materials has devoted so much time and effort to the determination of the best paints for the preservation of iron and steel against corrosion, it is deemed advisable to confine this report to other methods for such preservation and to give a brief synopsis of, and reference to, the results accomplished by the American Society for Testing Materials and other investigators in paint tests.

The matter was first taken up by the American Society for Testing Materials at its fifth annual meeting in 1902, at which time a resolution was adopted to appoint a Committee on "Preservative Coatings for Iron and Steel." The first report was made by that Committee in 1903, and beginning with that year the Proceedings contain a great deal of valuable information in Committee reports and in papers by individual members.

The Committee early realized the desirability of service tests on full-sized structures in ordinary service, and made such a recommendation in 1903. The report of that year gave the general requirements as a basis for the work of the Committee:

(1) Requirements for a satisfactory preservative metal coating.
(2) Methods used and suggested to determine whether the preservative coating is efficient.
(3) An index, with abstracts, if possible, of general and current literature bearing on this subject which has appeared in English, French, German and American publications.
(4) A classified list of all coatings used or suggested for the protection of iron and steel.

In addition, the Committee recommended a series of tests on steel panels, and in 1904 reported in detail the methods of preparing such panels for test.

The following Sub-Committees were appointed to study the various phases of the work:

"Standard Methods of Conducting Field Tests."
"Standard Methods of Conducting Service Tests."
"Permeability of Paint Films."
"Permanency of Paint Films."
"Preparation of Iron and Steel Surfaces."

In 1906 the Committee reported that arrangements were under way to paint a portion of the Havre de Grace bridge of the Pennsylvania Railroad with a large number of different brands and kinds of paints,

one portion of the bridge and several sheets of steel to be painted with each paint.

In 1907 the Committee reported that 19 paints had been applied to 19 panels of the bridge. Specifications for the preparation of the surface and application of the paint, together with instructions to the Director of Tests stationed at the bridge, had been issued by the Committee, but it was early found impractical to follow them under the conditions existing at the bridge.

The specifications required that all parts of the structure be cleaned free from mill scale, dirt, rust, etc., to clean bright steel. This was found impractical, as some of the members were badly rusted, especially in inaccessible parts, as between eye-bars on bottom chord and on latticed members. In such places it was found impossible to thoroughly clean without delaying the work to such an extent as to cause criticism from the railroad. The specifications also required that all paint be applied by the standard round brush. This was also found impossible on latticed members and between eye-bars on bottom chord, etc.

It was found that serious delay would have resulted from a rigid adherence to the original specifications.

For the above reasons the instructions were modified as follows:

(1) The surface of all accessible metal, in so far as is practicable, is to be cleaned in a workmanlike manner with putty and broad knives, scraper and wire brushes, so that all loose or easily detachable mill scale, rust and dirt are removed, as well as loose shop coat or "black oil" (by "black oil" is meant linseed). Any non-drying oil or grease on accessible parts is to be removed with either benzine or a torch.

(2) Where the shop coat is firm, hard, and in good condition, it is not necessary to remove it. This applies also to black oil.

(3) Field and shop rivets are to be wire-brushed, and, where necessary, this is to be followed by the knife or scraper, and hammer is not to be used.

(4) It is understood that the inside of columns and such other members difficult of access are not to enter into the test, and the above instructions for cleaning do not apply to them. They should, however, be cleaned in accordance with the ordinary methods of the contractor. The inspector is to make note of such members and include them in his report.

(5) Painting should follow cleaning immediately, and as many different paints are to be applied at the same time as the length and position of the scaffolds and expediency will permit.

(6) No paint shall be applied when the humidity is greater than 85 per cent.

(7) Since the net cost of all work is borne by the Committee, the inspector will see that the work is done with reasonable promptness, and will endeavor to keep the cost down as much as possible consistent

(8) All directions contained in the previous letter of instructions not herein modified are to remain in force.

The Committee also adopted the following rules for

"METHOD OF INSPECTION OF CONDITION OF PAINTS UPON HAVRE DE GRACE BRIDGE."

(1) Inspection to be made every six months, unless for sufficient reasons the Committee desires more frequent inspections, by an official inspector. Notice of each inspection is to be sent out previously to every member of the Committee, with the endeavor to have the Committee represented at each inspection.

(2) As far as practicable, a photograph should be taken at each inspection by a thoroughly competent photographer, preferably the inspector, care being taken to obtain negatives capable of enlargement and microscopic examination. A scale should be photographed in connection with the object.

(3) Character of gloss, to be noted by the inspector, whether high, moderate, dull or flat.

(4) Relative absorptive condition of each film when moistened with water.

(5) Relative toughness to be determined by cutting the film with a sharp knife, note being made whether elastic, tough, brittle or flaking, degree of adhesion being determined by the same test.

(6) Condition of surface to be noted, whether tendency to blister, alligator, scale, flake or powder (chalk), giving especial attention to the condition at angles and corners.

(7) Relative hardness to be determined by testing the films as to resistance to an edge of a cube of lead, tin, aluminum and zinc, respectively. (The details are now being worked out by Mr. Heckel, and report upon the method will be made shortly.)

(8) Note to be made as to the degree to which dirt has become attached to the surface.

(9) Condition of the surface as to powdering and general appearance, wear and weathering.

(10) When pitting has begun, the size, number, form, character and location of the pimple should be carefully noted, and the proportional increase since last inspection.

(11) Date to be noted on which repainting becomes necessary.

(12) These instructions are intended merely as a general guide to the inspector, who will be expected to make as complete observations as possible of all matters which appear to him to be worthy of report.

The 1908 report stated "The only example of an asphaltum coating thinned with a petroleum volatile solvent has failed to a marked degree after eighteen months' exposure."

In 1911, with one or two exceptions, the paints were affording excellent protection to the structure.

A further report of considerable interest appears in the Proceedings of the American Society for Testing Materials of the sixteenth annual meeting, June 24-28, 1913.

In 1908 a number of paints were also applied to wooden and steel panels exposed to the salt air at Atlantic City, N. J. The description of

these tests is contained in Vol. X, 1910, pages 79 et seq., Pro. Am. Soc. Testing Materials.

In 1910 the investigations on preservative coatings by the Committee had broadened to such an extent that it was reorganized, all former Sub-Committees being abolished and the following organization adopted:

(1) The Officers of Committee D-1 shall be a Chairman, a Vice-Chairman and a Secretary, to be elected annually.

(2) Members may be added to Committee D-1 at any time, by appointment by the Advisory Committee, after approval by the Executive Committee of the Society.

(3) The following standing Sub-Committees and their chairmen shall be appointed by the chairman of Committee D-1, abolishing all old Sub-Committees:

(a) Advisory committee of six to act with the Chairman, Vice-Chairman and Secretary, for the Committee between meetings.

(b) On inspection of the Havre de Grace bridge.

(c) On inspection of the wooden panels at Atlantic City.

(d) On the steel fence at Atlantic City, to collaborate with Sub-Committee of Committee A-5.

(e) On linseed oil.

(f) On the definition of terms used in paint specifications.

(g) On the influence of pigments on corrosion.

(h) On accelerated tests.

(i) On varnish.

(j) On testing white paints.

References to the Committee reports and articles of interest by individual members of the American Society for Testing Materials, together with the general conclusions reached by these and other investigators, are contained in the following pages.

Some of the experiences of those members, and other facts of interest set forth in the proceedings, are as follows:

"Almost no paint containing linseed oil as a constituent is impervious to water. The fineness of the pigment is a most important element in the water resistance of the layer. Protective coatings which dry by evaporation of the solvent seem to offer much more prospect of success. If our experiments are to be trusted, the protective coatings at present available are not as valuable as we have been hoping." Dudley, Vol. IV, 1904.

"Cement coatings must be kept in moist air at least 24 hours after being applied. Cement in extremely fine state of division will be necessary; 5 to 10 per cent. calcium chloride makes it set before drying." Newberry, Vol. IV, 1904.

"Paint must be rubbed in with a good stiff round brush. Proper cleaning and proper application of primary importance. Average quality of wood painting better than iron. Paint, then cover with paraffin paper, then paint." Sabin, Vol. IV, 1904.

"Tar residuum of petroleum mixed with some of the lighter oils (petroleum products) is the best preservative for train shed steel." De Wyrall, Vol. IV, 1904.

"Some of the ferric oxides are perfectly stable, are not affected by gases, and cannot change their composition." Toch, Vol. V, 1905.

"Use of flat brush should be prohibited. Round brush larger than a 6-o should not be allowed." Cheesman, Vol. V, 1905.

Articles and Committee Reports Contained in Proceedings of the American Society for Testing Materials Referring to Preservative Coatings for Iron and Steel.

Volume III—1903.

Report of Committee E—on Preservative Coatings for Iron and Steel.

Volume IV—1904.

Report of Committee E—on Preservative Coatings for Iron and Steel.

Results of an Investigation Concerning Causes of Durability of Paints for Structural Work.—Robert Job.

Preservative Coatings for Iron and Steel.—Cyril de Wyrall.

Volume V—1905.

Report of Committee E—on Preservative Coatings for Iron and Steel.

Proper Methods in Conducting Painting Tests.—G. W. Thompson.

The Practicability of Establishing Standard Specifications for Preservative Coatings for Steel.—Topical Discussion.

Protection of Iron and Steel Structures by Means of Paper and Paint.—Louis H. Barker.

What Is the Best Method of Painting Steel Cars?—Frank P. Cheesman.

The Effect of Electricity on Paint.—James C. Blanch.

Volume VI—1906.

Report of Committee E—on Preservative Coatings for Iron and Steel.

The Electrolytic Corrosion of Structural Steel.—Max Toch.

The Relative Corrosion of Wrought-Iron and Steel.—H. M. Howe.

The Corrosion of Iron and Steel—General Discussion.

Volume VII—1907.

Report of Committee E—on Preservative Coatings for Iron and Steel.

Report of Committee U—on the Corrosion of Iron and Steel.

The Corrosion of Iron.—Allerton S. Cushman.

The Influence of Stress upon the Corrosion of Iron.—W. H. Walker and Colby Dill.

Priming Coats for Metal Surfaces—Linseed Oil vs. Paint.—F. P. Cheesman.

Deleterious Ingredients in Paints.—L. S. Hughes.

Physical Testing of Oil Varnishes.—J. C. Smith.

The Physical Properties of Paint Films.—R. S. Perry.

Paint Legislation.—E. F. Ladd.

Volume VIII—1908.

Report of Committee E—on Preservative Coatings for Iron and Steel.

Appendix I—Paint Analyses.—P. H. Walker.

Appendix II—Paint Analyses.—P. C. McIlhiney.
Appendix III—Supplementary Reports of the Director of Tests.
Reports of Committee U—on the Corrosion of Iron and Steel.
Electrolysis and Corrosion.—A. S. Cushman.
The Relative Corrosion of Steel and Wrought-Iron Tubing.—H. M. Howe and Bradley Stoughton.
General Discussion on Corrosion.
The Analysis of Oil Varnishes.—P. C. McIlhiney.
Certain Solubility Tests on Protective Coatings.—G. W. Thompson.
The Inhibitive Power of Certain Pigments on the Corrosion of Iron and Steel.—A. S. Cushman.

Volume IX—1909.

Report of Committee E—on Preservative Coatings for Structural Materials.
Report of Committee U—on the Corrosion of Iron and Steel.

Volume X—1910.

Report of Committee A-5—on Standard Specifications for Steel.
Report of Joint Sub-Committee in Charge of Erection and Painting of Steel Test Panels at Atlantic City.
Report of Committee D-1—on Preservative Coatings for Structural Materials.
Report of Sub-Committee B—on Inspection of the Havre de Grace Bridge.
Report of Sub-Committee C—on Inspection of the Wooden Panels at Atlantic City.
Report of Sub-Committee E—on Linseed Oil.
Report of Sub-Committee G—on the Influence of Pigments on Corrosion.
Report of Sub-Committee I—on Varnish.
Some Exposure Tests of Structural Steel Coatings.—C. M. Chapman.
Vermilion Paint for Railway Signals: Results of an Investigation.—Robert Job.
Another Solubility Test on Protective Coatings.—G. W. Thompson.

Volume XI—1911.

Report of Committee A-5—on the Corrosion of Iron and Steel.
Analysis of Results of Official Inspection of Fence Wire Tests, Carnegie Technical Schools, Pittsburgh, Pa., November 30, 1910.
Report of Committee D-1—on Preservative Coatings for Structural Materials.
Report of Sub-Committee B—on Inspection of the Havre de Grace Bridge.
Report of Sub-Committee C—on Paint Vehicles.
Report of Sub-Committee D—on the Atlantic City Steel Paint Tests.
Report of Sub-Committee E—on Linseed Oil.

Report of Sub-Committee F—on the Definition of Terms Used in Paint Specifications.

Report of Sub-Committee J—on the Testing of White Paints.

The Value of the Sulphuric Acid Corrosion Test.—C. M. Chapman.

The Marked Influence of Copper in Iron and Steel on the Acid Corrosion Test.—W. H. Walker.

Some Tests on the Rate of Corrosion of Metal Exposed to Locomotive Gases.—A. W. Carpenter.

The American Railway Bridge and Building Association assigned a Committee to report on the subject, and as that report contains in concise form some fundamental principles, it is reprinted here in full:

"As a number of separate and distinct operations are necessary in the proper performance of a job of structural steel painting it appears best that the subject be divided and the different stages separately presented. Also, in this discussion, the process of coating new steel, and the work of repainting old structures should not be confused.

"Scientific research and numerous practical tests have demonstrated the fact that certain paint pigments, though possessing excellent moisture repelling properties, will actually stimulate corrosion when applied directly to steel surfaces, while certain other pigments have a tendency to restrict and repress corrosion when used for primers and foundation coats. Because of this, we divide the pigments into rust retarding, and air and moisture excluding ones, using the first for priming and contact coats, and the latter, for finishing and exposed outer surfaces. The pigments used in steel protective paints of the first kind are principally, red lead, oxides and the like, while carbons, lampblacks, graphite, etc., belong in the other class.

"Shop Coating.—A rust retarding coat may be suitably compounded from red lead mixed with pure linseed oil. The average stock mixture may consist of from 25 to 30 lbs. of red lead to the gallon of oil. This mixture can then be reduced to the proper consistency at the time of application. A small amount of turpentine added to this brush coating will greatly help in its manipulation and will also provide for proper penetration. Red lead should always be mixed at the time of its application, for it settles quite readily, as it is an extremely heavy pigment. If so desired, the settling can be retarded, to a certain degree, by the addition of a small amount of asbestine (magnesium silicate) in the proportion of about 20 lbs. of red lead and 2½ to 3 lbs. of asbestine pulp to the gallon of linseed oil. A small amount of turpentine should also be added to this mixture for the purpose mentioned above. A good workman is required to properly apply red lead paint because of its more or less difficult application.

"Natural oxides have also grown to be very good for priming purposes, and very satisfactory results are recorded from their use. A number of consumers favor oxides because of their easier application and the less expert class of labor which is required to apply it. A saving

of from five to ten per cent., as compared with red lead paint, can thus be effected. Some concerns are using a combination of red lead and oxide and make good reports regarding it. A number of reliable paint firms have similarly composed products on the market, which are sold under certain trade names, and some concerns have adopted them as their standards.

"Although quite extensively used in former years, linseed oil is rapidly losing favor. It appears to be a universal opinion that linseed oil is not a desirable material for the prime coating of metals when used without the addition of pigments. A foundation coat of linseed oil is very often the direct cause of peeling and blistering of the other several coatings applied over it. The oil is seldom dried enough to insure close adherence to the metal surface which it covers before the other paints are spread over it. When the subsequent coats of paint are spread, the solvents and oils in them are bound to soften to some extent the underlying coat of oil, and the moderate heat of the sun alone is sufficient to cause the whole film to draw up, blister, and finally peel. Too much oil in a paint coating, particularly when the surplus is in or near the foundation coat, will generally cause blistering and peeling, regardless of the pigments used in the coatings. If, on the other hand, the erection or final completion of an oil-coated structure should for some reason become delayed, this oil film, which deteriorates much faster than a paint coating, will have practically perished; its surface will be morbid and dead and will not have strength and stability enough to carry any subsequent coats, which when applied over this kind of a surface, will also peel.

"FIELD COATINGS.—Paints containing the same kinds of pigments as for shop coatings, can be successfully used for the first field coat, providing it is covered with another elastic outer coating. If that is not done, paints suitable for finishing coats should be applied, and the first field coat omitted. Red lead or oxide priming should be darkened for this coat by adding carbon or lampblack in the proportion of 90 to 95 per cent. of the reds and 5 to 10 per cent. of carbon mixed. The addition of this black will not only help to make the coating more elastic, but will act as a guide to determine if the former surface is being completely covered because of its darker shade and the shade is also brought nearer to the color of the black finish coating.

"Carbon, lampblack and graphite pigments, singly or mixtures of them, have given best satisfaction as outer surface and finishing paints. These, combined with some inert and reinforcing pigments according to special formulas form the basis for nearly every brand of paint for the satisfactory metal coatings on the market. The addition of some high grade gum like 'Kauri' improves a finishing paint greatly, producing more elasticity, resistance and life. It is, of course, just as essential that the oils entering into the makeup and composition of the various paints are of the

duties of passing on the merits of goods purchased should be very alert and strict in regard to linseed oil. Paints containing tar, or those with a tar base, should not be used on steel structures exposed to the sun and weather, as tar-paint films rapidly check, crack and 'alligator.'

"REPAINTING.—When for any reason it becomes necessary to repaint an iron or steel structure, the paint should never be applied in wet or freezing weather, and the surface should be freed absolutely from all scale, rust, dirt, etc. It is not sufficient to merely apply a fresh coat of paint over an old paint surface under which traces of paint corrosion appear, for while the new paint will cover up the old surface, and may adhere firmly to it, corrosion goes on beneath the paint just the same. Freeing from rust and corrosion and perfect cleaning are positively necessary. When for some reason it is not possible that the entire structure can receive a coat of some rust-retarding primer, the parts cleaned and freed from rust, and all the exposed surfaces, at least, should be touched up with either a red lead or oxide primer, before the finishing coat is given. The use of turpentine in the paint applied over the old surface is advised, as turpentine is a penetrant, providing the penetration and adhesion between the old paint film and the new coat.

"Although more expensive, cleaning by sand blast is much more thorough than the hammer, chisel, scraper and wire brush method, and the greater cost is readily offset by better results in the end. The sand blast method thus far has not been very extensively used, so the committee has not been able to gather full data as to the cost, etc., but we believe that the matter is worthy of deliberate consideration. Where the sand blast has been used, the steel so cleaned and the steel has been painted promptly, it has not shown signs of corrosion again nearly as quickly as steel cleaned by hand.

"Occasionally we notice defects showing up here and there on a steel structure within an unusually short time after the completion of the painting. On looking into the matter we find that nothing extraordinary has occurred during the progress of the work. Everything has been handled in the usual way, the general course of mechanical procedure has been followed, and still improper results are appearing. We recall no acts of our own to which to lay the blame and are finally compelled to look for the cause previous to our own handling of the work, or to the priming, which was done at the works or in the mill. We are not certain beyond a doubt, so we decide to visit a mill, and there make personal observations, which may very probably result as follows: In one part of this enormous plant we find the inspector busy in the pursuit of his duties, checking, comparing specifications, testing, weighing, and attending to the many details connected with his work. In the meantime, we notice in another remote part of the place a bunch of unskilled laborers mopping paint onto some steel that had been sent along for priming, using large 6 in. or 8 in. flat brushes, and covering over mill scale, rust, dirt and other imperfections, each and every one a destructive agent and an enemy to the life of steel. We observe all these stimulators

of corrosion brushed over and covered up with paint, but not removed, and so the march of the corroding process is sure to go on. We next pay attention to the paint they are using and learn that the package, which was opened some time ago to be inspected and was left standing uncovered all this time, had contained the standard paint as specified, but now, through neglect to properly cover, is no longer fit for the purpose used. On examining the contents of the package closely, we also notice that the paint is scarcely stirred up, and we see that the oily substance from the top of the mixture is first used, and as the work progresses and the material is consumed, the paint becomes heavier and intermixed with more or less pigment, until when the lower part of the package is reached nothing is left but a semi-dry pigment, which will no longer spread under the brush. Now, to assist in brushing, the men reach for the benzine can and reduce the paint with it, destroying what little life the paint had first contained. In this way a number of different surfaces and films are created on the same structure, and from the same package of the so-called protective coating.

"We proceed further, and find at other parts of the mill, though this time under a covered shed, more laborers applying a shop coat to other sections and parts of the structural steel. Here we notice exhaust pipes of all kinds steadily discharging vapor and moisture which finally settles and deposits on the steel. Under such conditions the steel cannot be perfectly dry, however much it may appear so, yet the painting is done just the same; these layers of moisture are enclosed between the surface and the steel, and the paint, which is supposed to close the pores and firmly adhere to the steel, is merely attached in some places and spots, and a weak foundation is created which is absolutely unfit to receive and successfully hold subsequent coats of paint.

"While we have gathered all this valuable information the inspector has found an opportunity to inspect the painting on these various sections of the steel. He looks at the job, and as it looks uniform in color, he regards it as properly done, because it is outwardly covered over with paint. The material is consequently passed, loaded and shipped.

"The foregoing illustration may appear somewhat severely drawn, and the situation presented greatly exaggerated; nevertheless, if a number of troublesome cases were thoroughly sifted, the illustration, in part, or in whole, would be identical with the underlying cause of the trouble.

"It must not be construed that our illustration is intended to cast any reflections upon the inspector or his methods. On the contrary, it is sought to imply that he uses his principal efforts in a direction considered primarily important, which is the correct fabrication of the parts composing the structure. No matter how diligent and untiring an inspector may be, it is not possible for him to be in a number of places at the same time, for, in large plants where modern methods are pursued in the manufacture and assembling of steel, the various departments are sometimes miles apart.

"Of course, not all failures are due to work which was first painted at plants, for often, even among so-called intelligent mechanics, the belief still exists that anything in the way of paint is good enough for priming purposes, so long as it is going to be covered again with paint, thus entirely ignoring the fundamental principles of a correct foundation.

"It may, therefore, be suggested that considerable attention be given to the education of men who deal in, or supervise the erection and maintenance of steel structures, so that greater interest in the problem will be aroused, better co-operation between the various departments effected, and the proper men chosen to handle the different lines of work."

INFORMATION RECEIVED FROM THE ROADS REPORTING.

Nineteen roads reported on the use of paint, 2 on the use of blast boards and 4 on encasement with concrete.

PAINT.

PRIMER (OR SHOP COAT).

Number Using	Kind of Paint	Composition	Remarks
1	Lamp Black	(Not given)	None
10	Red Lead	(Average) 30 lbs. Red Lead, 1 gal. Linseed Oil	None
2	Iron Oxide	1 gal. Red Iron Oxide, 2 gals. Linseed Oil 1 pt. Coach Japan	None

FIELD PAINT.

Number Using	Kind of Paint	Composition	Remarks
1	First Coat Oxide of Iron; Second, Lamp Black	(Given above) (Not given)	None
2	Silica (2 Coats)	Linseed Oil, 63%; Pigment, 29%; Turpentine Dryer, 8% (by wgt.); Composition of Pigment (by wgt.), Lamp Black, 27%, Silica, 58%, Red Lead, 10%, Graphite, 5%	In use 5 years and gave good results
2	White Lead	92½ lbs. White Lead, 7½ lbs. Graphite (ground in oil)	Lasts from 3 to 5 years
1	Iron Oxide	(Given above)	None
2	Graphite and Red Lead	Equal parts of Graphite and Red Lead ground separately in Linseed Oil, then mix and grind together	Average life for two coats about 7 years
3	Carbon	Not given. (Probably some forms of Graphite and Red Lead)	Average life about 4 years
3	Coal Tar (Used for Steel Exposed to Brine Drip)	(1:4:6 Mix.) 16 parts Coal Tar, 4 parts Cement, 1 part Kerosene Oil	In good condition after 4 years

BLAST BOARD.

The two roads reporting agree that concrete encasement, when subjected to the blast action of locomotive exhaust, must be protected by some kind of a blast board and recommend the use of steel plate,

cast-iron (exposed surface chilled) and vitrified and glazed tile. To date the use of the steel or iron blast board has proven effective.

The Kansas City Terminal Railway Company is conducting experiments with the use of transite board and means of fastening to the structure.

ENCASEMENT WITH CONCRETE.

The four roads reporting recommend the use of concrete for the protection of steel of highway bridges passing over railway tracks, and the protection of the concrete from blast action as given above.

CONCRETE ENCASEMENT.

Concrete encasement as a protective agent for that portion of steel structures exposed to the blast and gases of locomotives has come into use due to the trouble experienced with paint and to the cost of maintenance of the same.

That concrete properly applied is an ideal protection will, we believe, be conceded by everyone interested, even though they do not generally use it.

The use of the concrete encasement is in a way limited by railorads to undercrossings and to city bridges where the headroom is close and the railroad traffic heavy.

Painting.—In the above locations protecting floors by the use of paint is at best unsatisfactory and the cost while varying with the conditions will be somewhere in the neighborhood of $1.25 per ton per year. A fair average relation of weight to area is .065 square ft. per lb. of metal, this giving, using the above value, a cost of 0.96 cents per square ft., per year, for painting.

Poured Encasement.—If the floor is protected by the use of concrete encasement poured in place, the cost per square ft. will be as shown later approximately 25 cents per square ft., the encasement being three in. in thickness.

Gun Encasement.—Encasement of the floor by use of the cement gun, the encasement being three in. in thickness, will be as shown later approximately 23 cents per square ft.

The Committee has written to the several roads regarding their experience with encasement and the following extracts from the replies have been received:

W. F. Jordan, Manager Grand Central Terminal Improvements, New York Central & Hudson River Railroad:

"The cement gun is being used at the Grand Central Terminal for fireproofing and protecting a part of the steel structure of the Grand Central Terminal Improvements. The yard is in two stories, the upper tracks being supported on a steel structure with concrete jack-arches. It was necessary to get the upper tracks in service at an early date, so the fireproofing of the exposed parts of the steel below the jack-arches was not done at the time the floor was built.

"The lower parts of the beams, the girders and columns are now being fireproofed with the cement gun, using a minimum thickness of 2 in.; the average thickness is from 2½ to 3 in., as in the angles and around the stiffeners there is generally more than the minimum thickness.

"The fireproofing is reinforced with a wire mesh, 1½x1½ in. of No. 12 wires; this is attached to ¼ in. rods, which are bent around the steel and fastened to it.

"The mixture has generally been 1 to 3, but in cool weather, and where the steel is subject to vibrations from the trains running on it, a 1 to 2 mixture is found to be more economical, as it is not as likely to drop off. It is necessary with this machine to use fine sand, as sand with pebbles in it clogs the hose; all of the sand, therefore, has to be carefully screened.

"We find that a cubic foot of 1 to 3 mixture, when weighed in a box of 1 cubic ft. capacity after being moderately shaken down, weighs 93 lbs.; if this mixture is wet and applied with a trowel, after setting it will weigh 127 lbs. to the cubic ft.; when shot through a cement gun onto a steel structure and set up, it weighs 144 lbs. per cubic ft. From this you will get an idea of the density of the fireproofing made with this apparatus.

"In applying the mixture of sand and cement with the cement gun from 20 to 25 per cent. of it is lost. Some bounces off as it strikes the structure, some is shot by the steel in working around the angles and to get a smooth surface the mason scrapes off the irregularities, and to get a good surface it is floated.

"The labor required to operate one machine is as follows:

1 Foreman,
1 Operator of the machine,
1 Nozzleman,
2 Masons for floating,
4 Laborers screening, mixing and charging the machines.
Carpenters are used when necessary to erect scaffolds.

"One of these machines uses compressed air to the amount of 100 ft. of free air per minute at a pressure from 35 to 40 lbs.

"The hose through which the mixture is conveyed wears out quite rapidly and renewals amount to about $1.00 per day.

"We have averaged covering about 500 square ft. per day of the thickness mentioned above.

"This method would appear to give an excellent protection for the steel. The material is very dense and the method of application such that every inch of the structure is uniformly protected. The great thickness used in this work is due to the municipal laws requiring at least 2 in. of fire protection."

J. J. Yates, Bridge Engineer, Central Railroad of New Jersey:

"It is our practice, wherever practicable, to protect the steel of highway bridges or structures over our tracks by encasing in concrete. Where in close proximity and subjected to the blast of the exhaust from the stacks of locomotives, this has not proven altogether satisfactory.

"A concrete floor was installed in our bridge over the Pennsylvania Railroad at Newark, N. J., at which point there is only a clearance of about 12 in. above the stack. Within six months' time the concrete over the exhaust had been blown off to a depth of about 2 in. and it is now contemplated to use a 7/16 in. steel plate to protect the concrete. This type of steel plate protection was installed about two years ago by the Pennsylvania Railroad when they renewed their bridge over our tracks at Elizabeth, N. J., the previous bridge being so badly disintegrated by gases as to require renewal. Up to the present time this has proven very satisfactory and looks as if it were still good for two or three years. The original bridge was built about 1892.

"We have experimented with paints in the protection of steel work from exhaust but as yet have found nothing of any value. Our practice at the present time is to protect such portions as it is possible by encasing in concrete or by cast-iron, steel plates or wood, the cast-iron or steel plates being used when the structure is close to the exhaust of the locomotive.

"At our Newark bridge above referred to, before putting in the concrete we had a wood protection of hard pine which it was necessary to renew about once in three months, and, on the whole, offered a very poor protection, as pieces of wood were being constantly blown off, exposing the steel work."

W. F. Steffens, Engineer of Structures, Boston & Albany Railroad, Reporting to the New York Central Lines Bridge Committee, June 20, 1912:

"We have just completed at Tremont Street, Boston, a bridge over four tracks of the Boston & Albany Railroad. The minimum clearance from top of rail to under side of bridge is 15 ft. 1¾ in. It is evident, therefore, that the top of stack of the highest locomotive passes the bridge by but a few inches clearance. The old structure was of the usual open-floor type, with pony trusses, was built in 1889 and when removed was practically deteriorated to not less than 50 per cent. of the original sections, where exposed to gases.

"The new structure is of plate girders, with a floor of total depth of about 2 ft. 1 in. consisting of 15-in. beams spaced 1 ft. 6 in. center to center and incased entirely in concrete to form a solid slab, upon which the rails of the Street Railway Company and the paving are laid. The concrete is supported under the flanges of the beams by means of a net work of ¼ in. rods attached to the beams by means of thin hangers of strap steel 1/16 in. by ½ in. section hooked over the top flanges.

"It was very evident that under the severe conditions existing at this structure, the concrete protection would soon be worn away by blast action. To prevent this, we embedded in the concrete over the center line of each track a series of cast-iron blast guards 1 in. thick by 20 in. wide and in convenient lengths, attaching these to the concrete by means of hook anchors into the slab. The exposed surface of the cast-iron was chilled in order to harden it.

"To date this blast guard construction has demonstrated that it will be effective indefinitely in protecting the concrete undersurface. The blast strikes the plate and is deflected horizontally as intended.

"At the large bridge at Worcester, Mass., for the section over the New York, New Haven & Hartford Railroad, we have been limited by the court to the minimum 18 ft. 0 in. prescribed by the Railroad Commissioners. For the protection of the surface exposed to direct blast action at this greater distance above the tops of stacks, we intend to specify a special vitrified and glazed tile."

O. E. Selby, Engineer of Bridges and Structures, The Cleveland, Cincinnati, Chicago & St. Louis Railway:

"We have used concrete protection on some structures over railroad tracks with entire success. It is necessary to apply the concrete to a mesh of expanded metal or wire, and secure this mesh to the steel work at frequent intervals, also to protect the underside of the concrete casing from abrasion from the locomotive exhaust. For this latter purpose, we have used a protection plate one-half inch thick applied to the underside of floor beams, girders, etc., and made a part of the bottom flange, although it is not included in the computed flange sections. This protection plate extends 2 in. beyond the other flange plates and forms a shelf for the support of the concrete casings above. The oldest structure with this protection plate is about five years old and is in perfect condition as regards that detail."

G. E. Tebbetts, Bridge Engineer, Kansas City Terminal Railway:

When the Kansas City Terminal Railway Company took over the Kansas City Belt Railway to be used as their main line, there were among other structures four overhead highway viaducts which were of the encased type, i. e., having the floor system protected by concrete. A brief description and the results of a recent inspection may be of value.

One of the bridges was erected in 1903 and the other three in 1906.

The one erected in 1903 was of a through-girder type, 64 ft. long with suspended floor beams, the bottom flanges of the stringers flush with the bottom flanges of the girders.

The plans called for 1½ in. of encasement held in place by No. 10 gage, 3 in. mesh, expanded metal and ½ in. bolts, mortar to be 1:2:4 mixture. The roadway floor and sidewalk to be 1:2:4 concrete 5 in. thick reinforced with expanded metal. All steel encased unpainted.

The bridge was constructed as described, except that the encasement varied from 1½ in. to 3 in. in thickness, in general being 2 in. The concrete was put in dry and tamped and the mortar for the encasement was also made stiff, being rammed into the forms. The bottom board was held in place by bolts, and after the forms had been filled the bolts were tightened to force the mortar onto the steelwork. No waterproofing was used. Overhead clearance was 19 ft. 0 in.

Recent inspection showed the encasement on underside of floorbeams, stringers and girders over main track nearly all gone. The encasement

over industry tracks was in a little better condition but concrete was missing in quite a few places, notably lower flanges. The lower surface of floor was wet. Samples of concrete were taken and tested for excess of sulphur, but no excess was found.

It was concluded that most of the trouble was due to the seeping of water through the cracks in the concrete floor and also between the encasement and the steel; this action loosening and cracking the concrete and rusting the reinforcement, finally causing the concrete to drop off.

On the three structures erected in 1906 the encasement work was in about the same condition as the one above described, the cause seeming to be the same, i. e., the seeping of water down between the steel and the concrete.

On the new structures, the Kansas City Terminal Railway Company is building, the encasement is applied in the majority of cases by use of the cement gun.

Cement Gun.—This machine consists essentially of a hopper into which the cementitous materials, made up of one part Portland cement to three parts dry screened sand, are placed; a hose connected to the bottom of the hopper, through which the mixture is forced by air pressure; a nozzle at the end of the hose, to which another hose supplying water is attached for hydrating the materials.

At the end of the hose is a cylindrical nozzle having an annular ring at its base, to which the hose delivering the water is attached. This water is delivered inside the nozzle in the form of a fine spray, through which the materials from the gun pass. The nozzle is made of brass, and to prevent wear on the nozzle proper a rubber lining is used. This lining can be replaced whenever necessary.

Before adopting the cement gun, the claims of the company selling it were investigated and test panels were encased. The conclusion reached was that if the cost was not too great, it would solve the problem of encasement.

Comparative estimates made are shown below:

Encasement by pouring in forms. Encasement to be 3 in. in thickness. Mixture to be 1:2:4 concrete. Reinforcement, wire mesh and bars.

Stone, 1 cu. yd., @ $1.25	$1.25
Unloading 1 cu. yd., @20c	.20
Loss in handling, @ 5 per cent	.07
Sand, ½ cu. yd., @ 60c	.30
Unloading ½ cu. yd., @ 6c	.03
Loss in handling, @ 5 per cent	.02
Cement, 1¾ bbls., @ $1.25	2.19
Unloading 1¾ bbls., @ 5c	.09
Loss in sacks, @ 5 per cent	.03
	$4.18

One cubic yard equal to 108 sq. ft., 3 in. thick.

Cost of material per sq. ft.	$0.039
Forms $1.63 BM. @ .050	.081
Mixing and placing at $5.40 per cu. yd	.050
Insurance on payroll @ 5 per cent	.003
	.173
Overhead and profit @8 per cent + 15 per cent = 23 per cent.	.040
Cost per sq. ft. of encasement=.216	
Encasement per sq. ft.	.216
Mesh No. 3 @ $0.06	.018
Bars No. 5 @ $0.03	0.15
Total cost per sq. ft.	.249

Say 25 cents per sq. ft.

Encasement by use of cement gun. Encasement to be three inches in thickness. Mixture 1:3 mortar. Reinforcement, wire mesh and bars. Average number of square feet covered in a day of 10 hrs., 275 sq. ft. Loss due to gun work, 20 per cent. Loss due to handling sand, 30 per cent. Quantity of sand used in placing 275 sq. ft. three inches thick, 4 cu. yds.

Sand, 4 cu. yds., @ $0.60		$2.40
Unloading and screening 4 yds. @ $2.51		1.00
Cement, 5½ bbls., @ $1.25		6.88
Unloading 5½ bbls. @ $0.15		.83
Loss in sacks @ 5 per cent		.11
Water per day		.15
Gasoline for compressor, 12 gals. @ $0.15½		1.86
Oil waste and handling per day		.60
		$13.83
1 foreman 10 hrs. @ 37.5		$3.75
1 finisher, 10 hrs., @ 35		3.50
1 nozzleman, 10 hrs., @ 32.5		3.25
1 gunman, 10 hrs., @ .30		3.00
2 laborers, 10 hrs., @ 22.5		4.50
1 boy, 10 hrs., @ .125		1.25
		$19.25
Repairs, etc., per day	2.00	
Scaffolding for 275 sq. ft. @ $0.15	4.13	
		6.13
Interest on gun, $3,000 @ 5 per cent	.41	
Insurance on payroll @ 5 per cent.	.97	
		1.38
		$40.59

Overhead and profit 8 per cent. and 25 per cent= 33 per cent	13.53
Cost of encasement	54.12
Cost per square foot	19.68
Mesh No. 3 per sq. ft. @ $0.06	.018
Bars No. 5 per sq. ft. @ $0.03	.015
	.2298

Say 23 cents per sq. ft.

A comparison of the above shows a saving of 2 cents per square foot in favor of the gun work over the poured encasement, and it might be stated that since this estimate was made we have received bids on actual work that check very closely with the above.

The steel work to be encased was designed with open holes 11-16 in. in diameter in webs, stiffeners and flanges, so that in placing and attaching the reinforcement there would be ample provision for rigid attachment to the structure. In attaching reinforcement to girder webs and other large surfaces, the bars were placed on small V-shaped iron saddles and wired through the webs to each other. On flanges the rods were run through steel eyebolts attached to the lower flange, the mesh being attached to the bars by wiring. At the junction of the concrete encasement with the floor, which is also of concrete, a splice was provided by use of mesh placed in the floor previously cast, this splice being four inches in width. Fig. 3 shows typical method of attaching reinforcement to girders

The steel girders were shipped from the shops with a shop coat of linseed oil, which was removed by the use of a caustic soda wash before encasement was started. All rust spots were removed with a wire brush.

Our experience has shown that the 1:3 mixture placed in the gun gives a resulting mortar of approximately 1:2½, this change being due to loss of sand. The sand must be nearly dry, the dryer the better, a mixture of coarse and fine grains giving better results with considerably less loss, than either the coarse or fine alone.

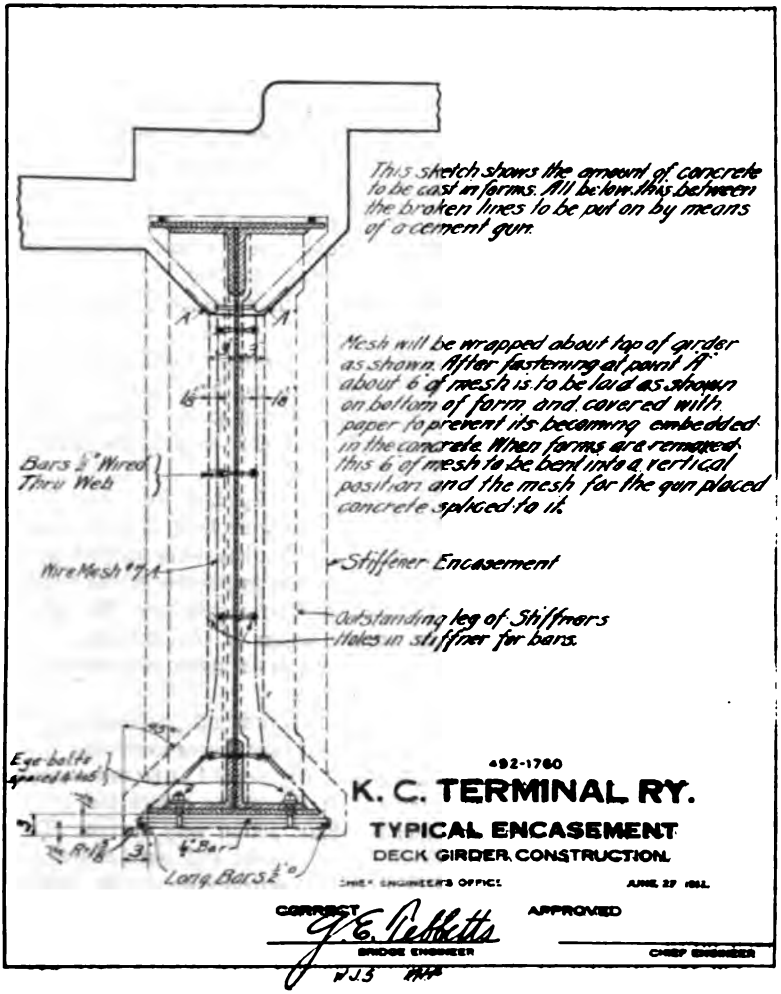
The sand must be screened as particles over ⅛ in. in diameter clog the gun and cause serious delays.

The compressor should be a machine of very ample capacity and an intermediate air storage tank is an advantage.

It was found that it was very difficult to encase the lower flange of a girder, especially so the lower face, and in our work we cast this portion in quite a few cases.

It was also a difficult proposition to get a good, clean job around stiffeners and sidewalk bracket members. On the brackets V-shaped forms were made and used as a backing for the gun work. As to finish, the appearance is fairly good, though far from the smooth, even lines of cast work and a great deal depends upon the finisher as to the final appearance.

One great advantage of the cement gun work, especially so in a large terminal proposition, is that the viaduct can be put in service and the


This sketch shows the amount of concrete to be cast in forms. All below this between the broken lines to be put on by means of a cement gun.
Mesh will be wrapped about top of girder as shown. After fastening at point "A" about 6" of mesh is to be laid as shown on bottom of form and covered with paper to prevent its becoming embedded in the concrete. When forms are removed this 6" of mesh to be bent into a vertical position and the mesh for the gun placed concrete spliced to it.
Bars ½" Wired Thru Web
Wire Mesh #7-A
Stiffener Encasement
Outstanding leg of Stiffners
Holes in stiffner for bars.
Eye-bolts spaced 6'-6"
Long Bars ½"
492-1760
K. C. TERMINAL RY.
TYPICAL ENCASEMENT
DECK GIRDER CONSTRUCTION
CHIEF ENGINEER'S OFFICE
CORRECT
APPROVED
BRIDGE ENGINEER
CHIEF ENGINEER

encasement work performed afterward when convenient without any material trouble.

Care has been taken in all the work on this terminal to build and waterproof the bridge floors so as to prevent the seepage of water onto the concrete, or encasement work, and we believe that waterproofing is an essential in good encasement work.

BLAST BOARDS AND SMOKE SHIELDS.

At bridges and undercrossings where the headroom is close, the lower portions of the structure should be protected by smoke shields if floor is not encased in concrete or by blast boards over each track if steel is encased. As shown below in the replies received by the Committee, the concrete encasement is rapidly worn away by sand blast action if unprotected. A variety of materials are in use for this purpose, including timber, steel, vitrified tile and asbestos boarding.

Below are extracts from replies to the inquiries sent out to the several roads:

G. E. Tebbetts, Bridge Engineer, Kansas City Terminal Railway:

Up to the present time we have not put into use blast boards on the work in hand, but the use of a ½-in. asbestos board 42 in. wide over the center line of each track is contemplated and will be put into service within the next few months.

The old structures on the Kansas City Belt Ry. had, in quite a few cases, headroom varying from 17 to 20 feet and were built over the main line where the grade was 1½ per cent., so that they were subject to a very violent sand blast action from exhaust. On inspection it was found that the girder flanges and other portions of floor system over the uphill tracks were practically worn away by the action of the exhaust. The wooden floor joists being worn away to a depth of about two inches by two feet in width over the center line of tracks.

Several materials were considered for experimental purposes and it was finally decided to try asbestos board in two very severe locations. The boards were placed at a height of 18 feet above the rail at Grand avenue and Troost avenue temporary bridges. At the above points the grade of the tracks was 1½ per cent. and the blast action very severe. The boards were left in service for about eleven months and were examined every month. It was found that there was practically no cutting action and the boards were finally removed when the temporary bridges were taken down.

On the showing of the experiment asbestos blast boards have been adopted for use on the terminal work and will be installed in service in the near future.

For additional information on this subject, see above letters from Messrs. Yates, Steffens and Selby, under the heading "Concrete Encasement."

The Committee submits the above for the information of the Association and believes that more time should be taken to go further into the use of this form of protection

Appendix B.

COLUMN TESTS.

The United States Bureau of Standards is now engaged in testing the first 18 columns mentioned in the program of tests submitted in the last report. The Committee witnessed the first test January 20, 1914. The specifications under which the tests are being made are as follows:

1. Before testing, each column should be examined carefully to determine the following points which shall be specifically noted on the detail drawing as well as on the test report sheets:

(a) Any deviations from the approved plan, either in weight, gage, section or make-up.

(b) Any imperfections in fabrication such as poor riveting, open joints, lack of true alinement, non-parallelism of parts, kinks or twists.

(c) Any imperfections due to careless handling during shipment, such as bent or dented edges, bent lattice bars or gusset plates or injury to base plates.

2. The shorter columns may be tested without counterweighting, but all columns, whose slenderness ratio is 85 or over, shall be counterweighted at the middle to the extent of one-half the weight of the column, exclusive of the base plates.

3. During the test, determinations of local stresses shall be made by strain gage measurements, located near the center and both ends of the column. The strain gage measurements near the center shall be made on the four legs of the channels, at the center of the channel web and on two or more lattice bars. At each end a similarly located set of measurements shall be taken just outside the wing plates of the bases, and also four measurements shall be taken to determine the stress distribution in the wing plates and channel webs close to the base, the last gage points being at least 6 in. from the ends of the column. The distance between gage points to be from 7 in. to 10 in. as may be convenient.

4. The strain gage measurements shall be supplemented by extensometer measurements on lenghts of from 4 to 10 ft. or longer if practicable. These shall be made on the flanges of the channels near the corners and also at the centers of the webs.

5. During the progress of the test, deflections in both planes shall be noted and recorded at each step as also any changes in shape of cross-section, opening of joints or slipping of lattice bars. The location of incipient scaling and the lines followed by the scaling are to be carefully noted and recorded.

6. The initial load shall be 1000 lbs. Then loads of 10,000 lbs., 15,000 lbs. and 20,000 lbs. shall be added, returning to the initial load after each application and determining permanent sets. From 20,000 lbs. proceed with increments of 1000 lbs. per sq. in. Measure the permanent sets after reaching loads of 20,000 lbs. per sq. in., 25,000 lbs. per sq. in. and 30,000 lbs. per sq. in., in case these loads are reached before the column fails. After each return to the initial load, when re-applying the loading, take the extensometer readings at every increment of 5000 lbs. per sq. in. until 25,000 lbs. per sq. in. is reached, after which point take the extensometer readings at every increment of 1000 lbs. per sq. in. up to failure, in order that it may be possible to plot a complete stress-strain diagram for each series of load applications.

7. Record the method of failure, whether by local buckling or deflection, as a whole and note carefully and record the condition of latticing, rivets and channels in the distorted areas.

8. After the ultimate load has been reached, at least one column of each section and ratio shall be further compressed to complete failure in order to emphasize the manner of failure. Photographs shall be taken of all columns where the failure has been thus emphasized, and of at least one column of each cross-section and ratio which has been loaded to failure.

9. As soon as any column is tested, a copy of the full test report shall at once be forwarded to the Chairman of the Sub-Committee in order that it may be submitted to the members for discussion.

The Sub-Committee is expected to use its discretion in varying these specifications as circumstances may require.

The Committee is co-operating successfully with the Special Committee on Steel Columns and Struts of the American Society of Civil Engineers. There will be no duplication of work, and all of the tests are planned to further our knowledge of the behavior of columns.

Appendix C.

SECONDARY STRESSES.

During the summer of 1911 a considerable amount of experimental field work was carried out, observations being made on several trusses representing quite a variety of design. The results were, in general, quite satisfactory and instructive. Your Committee has also made a theoretical study of some length on various types of trusses and has compared, to some extent, results obtained by calculation and by observation. The importance of the subject and the comparative newness of this class of calculations to most engineers has led the Committee to submit a very brief statement of the theoretical principles involved, and a complete set of calculations on one of the trusses which were investigated.

For the purpose of this report, secondary stresses will be considered under the following heads:

(1) Bending stresses in the plane of the main truss due to rigidity of joints, eccentricity of joints and weight of members.

(2) Bending stresses in members of a transverse frame due to the deflection of floor beams, and primary stresses in posts.

(3) Stresses in a horizontal plane due to longitudinal deformation of chords, especially the stresses in floor beams and connections.

(4) Variation of axial stress in different elements of a member.

(5) Stresses due to vibration of individual members.

(6) Methods of calculation.

Certain of these stresses, particularly those under (1) and (2), and, to some extent, those under (3), are capable of calculation by rigid methods of analysis. Granting the assumption of perfectly rigid joints, as in the case of well-riveted connections of continuous members, the results of calculations are quite as definite and certain as the primary stresses themselves. The problem may be illustrated by considering the case of a single triangle of members rigidly connected. If two of these are stressed in tension and the third in compression, the axial deformation of the three members tends to change the angles of the triangle by a small amount. The rigid connections prevent this, and the result is a bending of all members, the resulting stresses being a maximum near the joints. A similar result follows in a truss, but all the members are mutually interdependent, so that the calculations are somewhat lengthy, although the results just as definite as in the single triangle.

Your Sub-Committee has made a careful study of the secondary stresses falling under groups (1), (2) and (3), both theoretically and experimentally, and believes it possible to indicate with considerable definiteness the extent of such stresses under ordinary conditions. Those variations in stress noted under (4) and (5) have been observed in many cases in the experimental work which the Committee has carried out during several seasons. These stresses are not readily arrived at by theoretical analysis.

I—SECONDARY STRESSES IN THE PLANE OF THE MAIN TRUSS DUE TO RIGIDITY OF JOINTS, ECCENTRICITY OF JOINTS AND WEIGHT OF MEMBERS.

General Principles.—Stresses belonging to this category are capable of close theoretical analysis by methods which have been fully developed and which have been used for many years. A study of the action of a truss having rigid joints leads to certain general conclusions which are of much assistance in this connection. These may be stated, briefly, as follows:

(1) In any given truss the amount of bending, or the sharpness of curvature, produced in the members is, in general, proportional to the intensity of the primary stresses, that is, the larger the primary stresses the greater the deformation, both longitudinally and in bending.

The fiber stresses resulting from this bending, that is, the secondary unit stresses, are proportional to the bending and, therefore, proportional to the primary stresses. It follows that in any given truss, for any given method of loading, the secondary stresses bear a fixed percentage to the primary stresses, no matter what the amount of the load may be.

(2) Other things being equal, or similar, the percentage of the secondary stress is proportional to the distance to outer fiber in the plane of bending, and inversely proportional to the lengths of the members. When the members are symmetrical the secondary stresses will be proportional to the ratios of *widths* to *lengths*. Thus, if two trusses are compared whose general dimensions and moments of inertia of members are proportional, but the ratio of width to length of the various members of one truss is in all cases twice this ratio in the other truss, then the percentages of the secondary stresses in the first truss will be twice the percentages in the second truss. This relation comes about from the fact that in the two assumed cases, if the primary stresses are equal, the *angular* deformations of the members in the two trusses will be the same, and, for a given angular deformation, the resulting fiber stress is proportional to the ratio of width to length.

(3) The secondary stresses in any particular member are dependent upon the distortions of all the members of the truss, but, primarily, upon the distortions of the members of the particular triangles of which this member is a part and of the members of the adjoining triangles.

(4) Bearing in mind the above principles, it is possible to predict from calculations of typical trusses the secondary stresses in any particular type of truss in terms of ratio of widths to lengths of members with a considerable degree of accuracy.

(5) The more uniform the proportions of a truss the less, in general, will be the secondary stresses. Sudden changes in length, width, or in moment of inertia, are likely to result in relatively large secondary stresses.

(6) Trusses consisting of approximately equilateral triangles, and without hangers or vertical struts, present the most uniform conditions and will have, in general, the lowest secondary stresses. A truss com-

posed of right-angle triangles will show somewhat higher secondary stresses, and such stresses will be large if the ratio of height to panel length is large.

(7) Wherever hangers or vertical struts are used to support single joint loads, as in a Warren girder with verticals, or in a Pratt truss (at the hip vertical, or at the center vertical in the case of a deck bridge) the secondary stresses in the adjacent chord members are likely to be considerably larger than elsewhere. The best arrangement, so far as secondary stresses are concerned, is where each web member forms an integral part of the entire truss so that its stress will gradually change as the load progresses.

(8) Considering the fact that secondary stresses are, in general, proportional to the ratios of widths to lengths and considering the principles stated in the preceding paragraphs, it follows that the secondary stresses in trusses where the panels are subdivided, as in the Baltimore or Pettit system, are likely to be very high. In the case of pin-connected trusses this may also be the case with the top chord.

(9) Stresses due to eccentricity of joints are readily calculated. If the joints are rigid the effect of eccentricity is included in the other calculations. If the joints are pin-ended, then the effect of eccentricity is very simply determined. In general, an eccentric joint has the effect of introducing an "external moment" at the joint determined by calculating the resultant moment of all the primary stresses meeting at this joint. The maximum bending effect of eccentric joints is felt at the particular joint in question; at other joints the effect rapidly decreases and alternates in sign at successive joints in the same way as the bending moment in continuous girders at successive supports, due to a load on one span.

(10) The effect of the weight of the member can also readily be included in the rest of the calculations. Here, again, the effect of weight is very similar to the behaviour of a continuous girder supporting a uniform load. Illustrations of the effect of eccentricity, and also of weight, are shown in Plates I and II-b.

Results of Calculations and Experiments.—The results of calculations on several trusses, together with certain experimental results, are shown on several plates submitted herewith. These calculations will be briefly described, after which some general conclusions will be attempted.

Plate I shows results of calculations on a continuous top chord of a deck Pratt truss. The first figure below the truss diagram shows by the shaded portion the actual calculated secondary stress, both in pounds per square inch and in percentage of primary stress. Note that at the center point the secondary stress is about 33 per cent. of the primary. This high value is due to the distortion of the center strut. The third diagram below the one already mentioned shows what the secondary stresses would be under full live load if the middle vertical were lengthened by 3/64ths inch. The maximum here is about 16 per cent. The last diagram shows the stress due to weight of members.

Plate II-a and II-b give the truss diagram and the calculated secondary stresses in the top chord of a pin-connected Pettit truss. In both this and the preceding truss it has been assumed that the web members are free to turn on the pins, but that the top chord is continuous.

The upper diagram on Plate II-b shows the actual calculated secondary stresses. These run as high as 60 per cent. of the primary, due evidently to the deflection of the intermediate joint in the subdivided panel. If the two sub-verticals supporting the top chord are lengthened by 5/64th inch, these excessive stresses are practically removed, as shown by the second diagram of Plate II-b. The same result is obtained by omitting these sub-verticals, but the effect of weight of member is then greater. The last diagram gives stresses due to weight, with sub-verticals omitted. Plates III-b and III-c show calculated results on two ordinary trusses whose design is given in Plate III-a. The secondary stresses in the chord members of these two trusses are nearly the same. The lower chord on Plate III-b shows about 20 per cent. secondary stress, while on Plate III-c the percentage is a little higher. This is due to the fact that in the Warren system the effect of the hangers is greater.

Plate IV-a shows some very interesting results. They are obtained on a truss with sub-divided panels, Plate IV-b, in which the panel length is relatively small (12 ft., 9¼ in.). This is an actual design and was used in connection with a solid floor. The secondary stresses in the lower chord amount to from 50 per cent. to 60 per cent. of the primary stresses. The same is true in the end post. In the top chord the maximum is about 25 per cent. The very high secondary stresses in this case and in the top chord of the Pettit truss are due, primarily, to the very high ratio of the width of member to length.

Plates IV-c, d and e give the calculated results on a sub-divided truss of very short panel length (8 ft. 4 in.). The direction of bending as well as the per cent. of stress is shown in this case. Here the stresses run to nearly 100 per cent., obviously due to the very short panel length, together with the use of hangers.

Plate V-b shows the calculated secondary stresses, and Plate V-c the experimental secondary stresses in a pony truss, whose design is shown in Plate V-a. In the experimental work the bending stresses were determined by extensometer measurements on the four corners of the member. Considering the nature of such work, the agreement between the two sets of results is fairly good. Note that the secondary stresses in the lower chord are about 40 per cent., and in the upper chord about 25 per cent. of the primary stresses. These are fairly high, but in this truss the ratio of width of member to length is naturally very high, and when this is taken account of it will be found that these stresses are low as compared to some of the other results.

Plate VI shows calculated results on a viaduct tower. The results here obtained are very interesting. The three-story tower has no lateral

struts in the longitudinal plane, but in the transverse plane there is a strut at joint No. 3. The secondary stresses in the longitudinal plane are very small, while in the transverse plane they amount to about 15 per cent. of the primary stresses.

Calculations on a four-story tower, without lateral struts, are given in the adjoining figure. This shows a secondary stress of 12 to 15 per cent. at each joint.

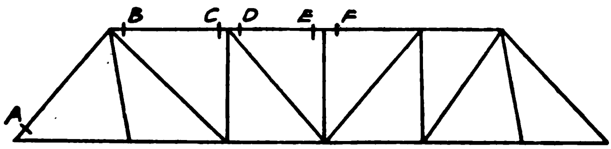
The explanation of the great variation in results is evident by a little study of the situation. In a two-story tower, or a four-story tower having no lateral struts, the vertical compression of the posts causes the first joint below the top and the first joint above the bottom to be bent outwards by the action of the diagonals. In the four-story tower the middle joint will tend to stand fast. The result is to bend the post outwards at alternate joints, and this will be the case in any similar tower of an even number of panels. In a three-story tower this alternating effect cannot take place, as both joints, No. 3 and No. 5, tend to bend outwards, and the diagonals connecting these joints resist this tendency. The insertion of a single strut at joint No. 3 tends to break up the tower into two parts, the upper part being a two-story tower, subject to considerable secondary stress.

The obvious conclusion to be drawn from this analysis is either to use an odd number of panels or to use struts at each joint.

Other Experimental Results.—In addition to the experimental results given on Plate V-c, a considerable number of results were obtained during the summer of 1911. A considerable proportion of these observations were made with respect to other features, such as effect of floor beams on vertical posts, and horizontal bending of floor beams due to stringer action. A number of these observations were, however, made with respect to secondary stresses in the plane of the main truss. The principal results are noted in the following tables:

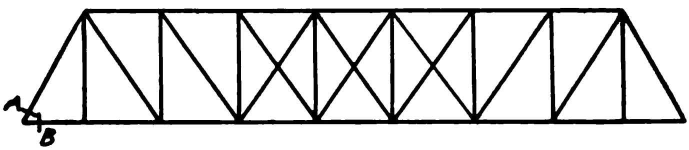
OBSERVED SECONDARY STRESSES ON VARIOUS TRUSSES
(See Plates VII for description of Trusses)

TRUSS "A". RIVETED TRUSS SPAN OF 159'-9"



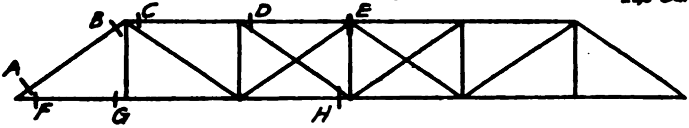
Members	Position of Extensometers	Primary Stress lb. per sq. in.	Percent Secondary Stress in Plane of Truss
End Post	A (Top Fibre)	3,300	19
Top Chord	B (Bottom Fibre)	3,200	3
	C (Top ")	2,900	52
	D (Top ")	4,400	6
	E (Top ")	4,200	16
	F (Top ")	4,300	7

TRUSS "B" PIN CONNECTED SKEW SPAN OF 176'-6"



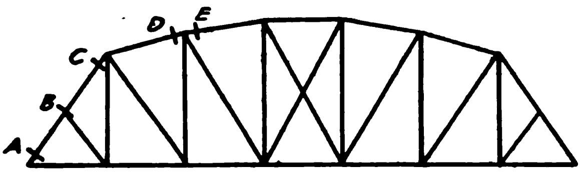
Members	Position of Extensometers	Primary Stress lb. per sq. in.	Percent Secondary Stress in Plane of Truss
End Post	A (Bottom Fibre)	5,500	23 (Eccentricity)
Bottom Chord	B (Top Fibre)	4,800	57

TRUSS "C" 104 FT PARTIALLY RIVETED PONY TRUSS (Diagonals are Eye-Bars)



Members	Position of Extensometer	Primary Stress lb. per sq. in.	Percent Secondary Stress in Plane of Truss
End Post	A (Bottom Fibre)	5,000	7
	B (Bottom ")	5,300	22
Top Chord	C (Bottom Fibre)	6,600	7
	D (Top ")	6,000	29
	E (Top ")	7,500	10
Bottom Chord	F (Top Fibre)	5,600	10
	G (Bottom Fibre)	5,900	24
	H (Bottom "	5,700	33

TRUSS "E" 182'-6" RIVETED DOUBLE TRACK SPAN



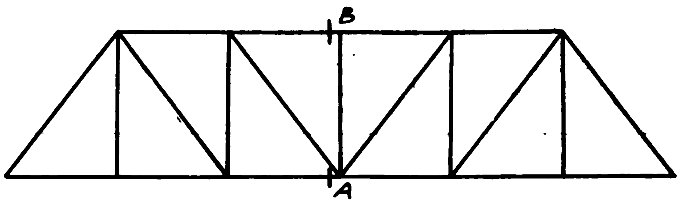
Members	Position of Extensometer	Primary Stress lb. per sq. in.	Percent Secondary Stress in Plane of Truss
End. Post	A (Bottom Fibre)	2,700	20
	B (Top ")	3,200	32
	C (Bottom ")	2,900	24
Top Chord	D (Top Fibre)	3000	29
	E (Top ")	3,100	23

In general these results correspond in magnitude with the theoretical results already discussed and confirm the general conclusions as to the presence of such stresses of relatively large values.

Trusses A and B are skew bridges and the secondary stresses in the members of the end panels are considerably affected by the lateral systems. In truss B, for example, although pin connected, the bending stress in the end lower chord is about 50 per cent. of the primary, due to the heavy lateral stresses. Truss E is a heavy double-track span with deep chords. Note the relatively large stress in the end post and top chord, due partly to the collision strut.

General Discussion of Results.—To assist in analyzing the results of the calculations and experiments, we have plotted the most significant of these on Plates VIII (a) and (b). On Plate VIII-c are also shown certain theoretical results of considerable value in this connection.

TRUSS "F" 132 FT SPAN. PIN CONNECTED, WITH RIVETED LOWER CHORD



Members	Position of Extensometer	Primary Stress lb. per sq. in.	Percent Secondary Stress in Plane of Truss
Bottom Chord	A (Top Fibre)	4,700	20
Top Chord	B (Bottom Fibre)	7,200	21

On Plates (a) and (b) are plotted maximum percentages of secondary stress in various members of thirteen separate trusses. These results are taken partly from Grimm's work on Secondary Stresses, partly from Part II, Johnson's "Modern Framed Structures," and partly from the calculations presented herewith. Bridge No. 11 is the one analyzed by F. C. Kunz in *Engineering News* of October 5, 1911. In all cases the percentages given are the maximum percentages of the secondary stress in the various members, but only those results are taken that occur when the primary stresses are large. In a few cases where the design is such that the primary stress is small, the calculated percentage of secondary stress has been somewhat reduced.

On Plate VIII (a) are plotted results on bottom chords and main diagonals and on Plate (b) results on top chord members and end posts.

All results are plotted with ratios of width of member to length as abscissæ and percentages of secondary stress as ordinates.

Referring to Plate (b) and noting the higher values, it will be seen that these occur generally in the end post, or in the end member of the top chord. The value for the top chord of the sub-divided Pettit truss No. 13 is also relatively high. This value of 60 per cent. is very high, but evidently the high ratio of width to length accounts, for the most part, for this high value. Noting trusses Nos. 4, 7, 8 and 11, all of the results are seen to be relatively low. These trusses are all ordinary single intersection trusses of modern design. The results on No. 6 are rather high in the end panel and end post. This is due to the use of a collision strut in this design. No. 10 is exceptionally high. This is the sub-divided Warren truss with very short panels.

Referring to Plate (a), it will be noted that the results are, on the whole, slightly larger relatively than those on Plate (b). This condition is due to the fact that nearly all the trusses are through bridges, which brings most of the load along the lower chord, so that the distortions of the vertical members affects the lower chord more than it does the upper chord. The high values of No. 10 and No. 4 are noteworthy. No. 4 is a modern design, but the height of truss is comparatively great so that the distortion of the verticals is relatively great. This affects the lower chord rather seriously. On both Plates (a) and (b) it is of interest to note that No. 9, the Pony-Warren truss, having relatively wide members, has a fairly small percentage of secondary stress, considering the width of the members. This is doubtless due to the favorable proportions of the triangles and to the relatively large sections of the floor beam verticals.

The truss whose analysis is given in Plates IV (d) and (e) is not represented in the diagrams here described, but the values will be seen to correspond very well with the others. The lower chord (Plate IV-c) has a ratio of width to length of about 0.24 and a maximum secondary stress of 100 per cent., or about $4 \times \frac{\text{width}}{\text{length}}$, while the upper chord and end post have ratios of about 0.12 and secondary stresses of 35-40 per cent., or say $3 \times \frac{\text{width}}{\text{length}}$.

On Plate VIII (c) are plotted some interesting theoretical results. Lines A, B, C and D show the results obtained on single triangles in which the primary stresses in all members are numerically the same, the stress in two of them being of one sign and the stress in the third being of opposite sign. Line A gives the maximum percentage of secondary stress which will occur in an equilateral triangle where all members have the same moment of inertia. Line B gives results for a right-angle triangle where the lengths of the members have the proportions 3:4:5. Line C gives results for an equilateral triangle in which one of the sides has an infinitely large moment of inertia. This condition gives rise to

much larger bending stresses in the other members. Line D gives similar results for the right-angle triangle.

Lines E and F give general results of various systems calculated by assuming a truss of indefinite length, and of certain proportions as between chord members and web members, and certain uniform stresses. These calculations are given on pages 484 and 486, Part II, Johnson's "Modern Framed Structures." While, of course, these results are different from what would be obtained on any given truss, they are very helpful as indicating what the necessary secondary stresses are under uniform and rather favorable conditions. Line E, for example, shows that in a long truss of Pratt or Warren system, without verticals, we cannot avoid secondary stresses of approximately 35 per cent., if the ratio of width to length is one-tenth. A detailed examination of the calculations referred to shows that in the chord members the percentage is likely to be as low as 30 per cent. along the center of such truss where the web members are not large, but may reach as much as 40 per cent. towards the ends, where the web members are nearly as large as the chord members.

Line F shows very clearly the effect of floor beam verticals on the loaded chord.

Effect of Secondary Stresses on Strength of Struts.—The bending moments at the ends of members caused by rigid joints are equivalent to a certain eccentricity of application of primary stress. Where the bending moments at the ends of a member are such as to cause the member to deflect in single curvature the eccentricities at the two ends will be in the same direction. In this case the effect of the resulting deflection will be to increase somewhat the bending moments along the center of the member above the calculated values. This increase will be approximately equal to the product of direct stress multiplied by the center deflection. The equivalent eccentricity due to secondary stress and the actual center deflection under certain assumed conditions may be readily determined so that the possible effect of the deflection may be estimated.

Suppose the ratio of the width to length be 1/10 and that the secondary fiber stress is 40 per cent. of the primary stress. Assume, further, that the radius of gyration $= r = .4 \times \text{width} = \sqrt{\frac{I}{A}}$. Then it can be shown that the equivalent eccentricity is closely equal to 1/6 the width of member, that is, the effect of secondary moments is equivalent to applying the direct stress at each end with an eccentricity of this amount. The deflection due to this condition in the case of single curvature is closely equal to $\frac{10\,s}{E} \times \text{width}$, where $s =$ unit compressive stress in member and $E =$ modulus of elasticity. Where $s = 10{,}000$ lbs. sq. in. the deflection is equal to width $\div 300$, or about 1/40 the original eccentricity.

This is a rough measure of the effect of deflection on the bending moments in the strut. We may, therefore, conclude that in struts of ordinary proportions this effect is quite small.

General Conclusions.—Considering the results of the observations and calculations above referred to, and the general principle that to a great extent secondary stresses are proportional to the ratios of widths to lengths of members, it may be said that the secondary stresses of the kind here discussed in ordinary trusses should not exceed 40 per cent. for a ratio of width to length of one-tenth, or, expressed more generally, should not exceed $4 \times \frac{\text{width}}{\text{length}}$. If sub-divided panels are not used, it is probably practical to keep the ratio $\frac{\text{width}}{\text{length}}$ sufficiently low so that the secondary stresses will not exceed 35 per cent.

In the bottom chords of through trusses a value of $5 \times \frac{\text{width}}{\text{length}}$ is likely to be reached, but here the ratio $\frac{\text{width}}{\text{length}}$ can be kept somewhat lower than in compression members, so that ordinarily the secondary stress need not exceed 30 to 35 per cent.

Special attention should be given to secondary stresses in trusses with sub-divided panels, as these are likely to reach very high values, due, primarily, to high ratios $\frac{\text{width}}{\text{length}}$, but also to the distortion of the hangers and sub-members.

THE THEORY OF SECONDARY STRESS CALCULATION.

The method of Secondary Stress calculation given in the following discussion is that set forth in Part II of "Modern Framed Structures" by Johnson, Bryan, and Turneaure. Let the dotted lines of Fig. 1 represent a portion of a truss before the application of the loads. After the loads are applied the various members elongate or shorten, depending upon the character of the stress in the members, and the truss deflects to the position shown by the light full lines.

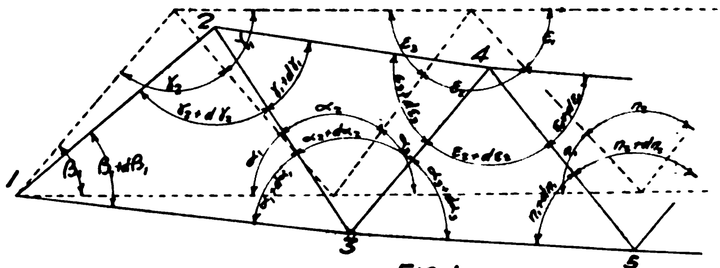


FIG. 1

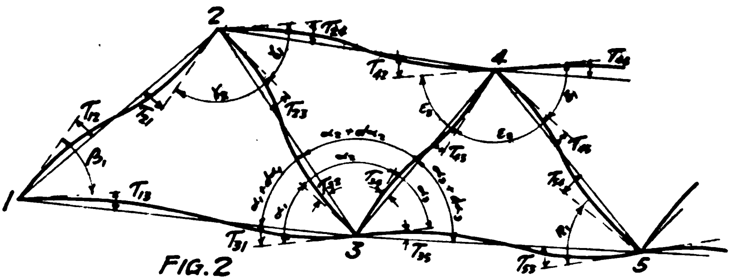


FIG. 2

This change of form of the truss calls for changes in the angles of the various triangles, depending upon the deformation of the members and the proportions of the triangle. The values of the angular changes can be calculated as soon as the size of members, form of truss, and loading conditions are known.

A convenient set of formulas for the calculation of angular changes can be derived by differentiation. Thus in Fig 3, let A, B, and C be the angles and a, b, and c the sides of any triangle. From Trigonometry:- $\cos A = \frac{1}{2bc}(b^2 + c^2 - a^2)$ ... Eq. (a)

The effect of positive differential changes in the length of sides a, b, and c on the angle A can be determined

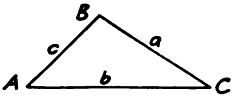


FIG 3

by partial differentation of Eq. (a). This is equivalent to deformation in all members due to tension. We have

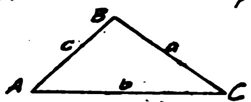


FIG 3

$$dA = \left(\frac{\partial a}{a} - \frac{\partial c}{c}\right)\cot B + \left(\frac{\partial a}{a} - \frac{\partial b}{b}\right)\cot C$$

If s_a, s_b, and s_c are the unit stresses in a, b, and c respectively, we have $\partial a = s_a\,a/E$, $\partial b = s_b\,b/E$ and $\partial c = s_c\,c/E$, from which we have

$$dA = \frac{1}{E}\left[(s_a - s_c)\cot B + (s_a - s_b)\cot C\right] \text{------} (1)$$

In the same way we find for angles B and C:-

$$dB = \frac{1}{E}\left[(s_b - s_a)\cot C + (s_b - s_c)\cot A\right] \text{------} (2)$$

$$dC = \frac{1}{E}\left[(s_c - s_b)\cot A + (s_c - s_a)\cot B\right] \text{------} (3)$$

As a check on the calculated values of angular changes in any triangle, we have $dA + dB + dC = 0$

In order to allow these angular changes to take place, as shown in Fig 1, the various members must be free to turn at the joints. The members in structures with riveted joints are not free to turn and the angles between the members retain their original values. In deflecting to the full line position of Fig 1 the members must be bent out of a straight line, as shown by the heavy full lines of Fig. 2. The members are therefore subjected to bending moments, depending upon the amount of bending as indicated by the deflection angles at each end of the member. From Mechanics, the relation between angular changes at the ends of a member and bending moments is found to be,-

$$M_{13} = \frac{2EI}{l}(2T_{13} + T_{31}) \quad \text{and} \quad M_{31} = \frac{2EI}{l}(2T_{31} + T_{13}) \text{------} Eqs(4)$$

where the various terms are as shown in Fig. 4, which represents the forces acting on member 1-3 of Figs 1 and 2. The signs of moments and values of T will be considered as positive when the bending produced is as shown in Figs 2 and 4. M_{13} and T_{13} indicate respectively the moment and inclination at the left end of member 1-3, and M_{31} and T_{31} indicate the corresponding quantities at the right end of the same member. The effect of the direct stress in the members has been neglected in Eqs(4)

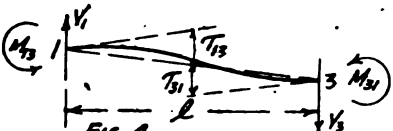


FIG 4

Since each joint of the truss considered by itself as a free body in space is in equilibrium, we can state an independent equation by placing equal to zero the sum of the moments at the ends of all members at any joint, provided the members are concentric so that the primary stresses cause no bending moment. Thus for joint 3 of Fig 2 we have

$$M_{31} + M_{32} + M_{34} + M_{35} = 0 \text{------------} Eq(5)$$

Substituting in terms of T, as in Eq's (4) we have,-

$$\frac{2EI_{31}}{l_{31}}(2T_{31} + T_{13}) + \frac{2EI_{32}}{l_{32}}(2T_{32} + T_{23}) + \frac{2EI_{34}}{l_{34}}(2T_{34} + T_{43}) + \frac{2EI_{35}}{l_{35}}(2T_{35} + T_{53}) = 0 \text{---} Eq(6)$$

In the same way an equation similiar to Eq (6) can be written out for each joint. The values of T in these equations are all unknown, and thus we have twice as many unknowns as there are members in the truss. At the same time we have only as many independent equations as there are joints in the truss, so that at present the equations can not be solved.

But from certain geometrical relations between the angles at any joint, the number of unknowns can be reduced to one at each joint. We will then have as many independent equations as unknowns, and a solution of the equations is possible.

Thus at joint 3 of Fig 2 we see that $T_{31} + (\alpha_1 + d\alpha_1) = \alpha_1 + T_{32}$, or: $T_{32} = T_{31} + d\alpha_1$

Also, $T_{31} + (\alpha_1 + d\alpha_1) + (\alpha_2 + d\alpha_2) = \alpha_1 + \alpha_2 + T_{34}$, or: $T_{34} = T_{31} + d\alpha_1 + d\alpha_2$

To sum up, we have

$$\left.\begin{aligned} T_{32} &= T_{31} + d\alpha_1 &&= T_3 + d\alpha_1 \\ T_{34} &= T_{31} + d\alpha_1 + d\alpha_2 &&= T_3 + d\alpha_1 + d\alpha_2 \\ T_{35} &= T_{31} + d\alpha_1 + d\alpha_2 + d\alpha_3 &&= T_3 + d\alpha_1 + d\alpha_2 + d\alpha_3 \end{aligned}\right\} \cdots \text{Eq's (7)}$$

Thus we have expressed the values of T_{32}, T_{34}, and T_{35} in terms of the unknown T_{31} and the known angular changes $d\alpha_1$, $d\alpha_2$ and $d\alpha_3$ which can be calculated by means of Eq's (1), (2), and (3). The angle T_{31} is then the only unknown at joint 3.

It will be well to give angle T_{31} a name and define its selection for any joint. We will call T_{31} the "Reference Angle" for joint 3, and for brevity will indicate it as T_3 (or what ever the joint number may be). It will be convenient to select the reference angle as the deflection angle of the first member encountered in passing around a joint in a clockwise direction, beginning on the outside of the truss. Thus in Fig 2, T_{24} or T_2 for joint 2, and T_{12} or T_1 for joint 1 are the respective reference angles. We can now transform the various T_s in Eq (6) into the form of Eq (7)

$$\left.\begin{array}{ll} \text{Joint \#1} & T_{13} = T_1 + d\beta_1 \\ \text{Joint \#2} & T_{23} = T_2 + d\gamma_1 \\ \text{Joint \#3} & T_{31} = T_3 + 0;\ T_{32} = T_3 + d\alpha_1;\ T_{34} = T_3 + d\alpha_1 + d\alpha_2;\ T_{35} = T_3 + d\alpha_1 + d\alpha_2 + d\alpha_3 \\ \text{Joint \#4} & T_{43} = T_4 + d\varepsilon_1 + d\varepsilon_2. \\ \text{Joint \#5} & T_{53} = T_5 + 0. \end{array}\right\} \text{Eq's (8)}$$

As $2E$ is common to all members of Eq (6) we can divide through by this term. Also for brevity we can denote by K the general term I/ℓ, giving to each K the proper subscript. It is evident that $K_{31} = K_{13}$, $K_{35} = K_{53}$, etc. Making these changes and substituting the transformed T_s in Eq (6), we have

$$K_{31}[2(T_3+0) + (T_1 + d\beta_1)] + K_{32}[2(T_3 + d\alpha_1) + (T_2 + d\gamma_1)]$$
$$+ K_{34}[2(T_3 + d\alpha_1 + d\alpha_2) + (T_4 + d\varepsilon_1 + d\varepsilon_2)] + K_{35}[2(T_3 + d\alpha_1 + d\alpha_2 + d\alpha_3) + (T_5 + 0)] = 0$$

which can be written

$$2T_3[K_{31} + K_{32} + K_{34} + K_{35}] + 2[K_{32}d\alpha_1 + K_{34}(d\alpha_1 + d\alpha_2) + K_{35}(d\alpha_1 + d\alpha_2 + d\alpha_3)] + [K_{13}T_1 + K_{13}d\beta_1]$$
$$+ [K_{23}T_2 + K_{23}d\gamma_1] + [K_{43}T_4 + K_{43}(d\varepsilon_1 + d\varepsilon_2)] + [K_{53}(T_5 + 0)] = 0 \text{ ----- Eq (9)}$$

Eq (9) is the general form of the independent equation for joint 3. A similar equation is to be written out for each joint. In general each equation contains as unknowns the reference T for the joint for which the equation is made up, and the reference T_s for the joints at the opposite end of each member entering the joint in question. The equation also contains certain known or absolute terms which depend for their value upon K and the deflection angles.

Thus the first term of Eq (9) is composed of T_3 multiplied by twice the sum of the K_s for all the members at joint 3. The second member of Eq (9) is equal to twice the sum of the products of terms composed of the K_s for the several members at joint 3 multiplied by the sum of all the angular changes from the reference angle up to the member in question. The remaining members of the equation are the deflection angles for the opposite end of each member entering joint 3 multiplied by the K for the member, the deflection angle being stated in terms of the reference angle of the joint containing the member, as in Eq's (8).

The equations similar to Eq (9) for each joint make up a set of linear simultaneous

equations which when solved will give the value of the reference angle for each joint. Then from Eq's (8) we can determine the values of the deflection angles at ends of each member. Substituting these values of the deflection angles in Eq's (4) we find the moments at the ends of each member. To determine fibre stresses we have the formula $f = Mc/I$ where f = fibre stress, M = bending moment, c = distance from neutral axis to extreme fibre of member, and I = moment of inertia of member. Substituting the moment as given by Eq (4) in this formula we have

$$f_{13} = \frac{2Ec}{l}(2T_{13} + T_{31}) \quad \text{and} \quad f_{31} = \frac{2Ec}{l}(2T_{31} + T_{13}) \text{ - - - - - - Eq's (10)}$$

Similar equations can be made up for any member of the structure.

The Effect of Eccentric Forces at a Joint. When the members at a joint are not concentric, as assumed in the derivation of Eq (5), we must include the moment due to eccentricity in the summation of moments at any joint. Let this moment for joint 3 be M_3. The value of M_3 can be calculated as soon as the eccentricities of the members and stresses are known. Eq (5) then becomes,

$$M_{31} + M_{32} + M_{34} + M_{35} + M_3 = 0 \text{ - - - - - - - - (11)}$$

The effect of this new term on the general Equation (9) is to add a term of the form $M_3/2E$ to the left hand member of the equation.

Formulation of Equations for Interior Joints. In some cases we have to deal with interior joints, as in the case of a structure with subdivided panels. Any convenient deflection angle can be taken as the reference angle, after which we proceed as for an exterior joint. An example of this kind occurs at joints 7 and 11 of the truss on page B 3, Appendix B.

Special Case. A new point comes up in calculation of angular changes in the truss shown on page B 3, one panel of which is given in Fig 5. The heavy curved lines show the probable bending of the members. Note that joint 7 causes a change in the curvature of member 5-9, so that 5-8-9 is not a true triangle in the sense of the triangles of Fig 2. But by introducing an imaginary member from 7 to 8, we can divide the figure into two real triangles 5-8-7 and 7-8-9. This new member 7-8 will be considered as having zero moment of inertia, hence $K_{78} = 0$. The unit stress in member 7-8 to be used in Eq's (1), (2), and (3) for the calculation of angular changes can be determined from the distortion of the truss along the line 7-8, for the loading conditions of the particular problem. From Mechanics, Distortion $= sl/E$ where s = unit stress and l = length of member. Let the calculated distortion along line 7-8 be D_{78}. Then we have $s_{78} = E\,D_{78}/l_{78}$, which is a quantity of the same dimensions as s_a, s_b, and s_c of Eqs (1), (2) and (3). For an example of such calculations see the problem worked out in Appendix B.

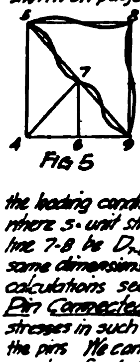


Fig 5

Pin Connected Structures with Riveted Top Chords. In calculating the secondary stresses in such structures we may consider that all the web members are free to turn on the pins. We can take account of this condition by assuming that the end moments for members free to turn on the pins are zero, and omit them in forming an equation of moments at the joint, as Eq (5). Also we assume that the moment of inertia of such members is zero, or that K = zero. In the calculations for angular changes, such members should, however, be included, the same as others that are rigidly connected.

SECONDARY STRESSES IN THE TOP CHORD OF A DECK PRATT TRUSS

Single Track Structure
Trusses 16'-0" c. to c.

Pin Connected Joints
Riveted Top Chord

Loading: Coopers E-60 Specifications: A.T.&S.F. 1902
Floor System; Floorbeams and Stringers, Ballast Floor.

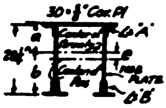


TABLE OF CHORD SECTIONS

MEMBER	WEB PLS	∠"A"	∠"B"	AREA	I	a	b	e
[illegible]	[illegible]	[illegible]	[illegible]	78.3 [illegible]	[illegible]	[illegible]	13.95"	1.85"
[illegible]	[illegible]	6×4×[illegible]	6×4×[illegible]	102.2 [illegible]	[illegible]	14.25"	14.065	0.52"
U_4U_5	[illegible]	6×4×[illegible]	6×4×[illegible]	111.7 in	13,270 [illegible]	14.25	14.625	0.50"

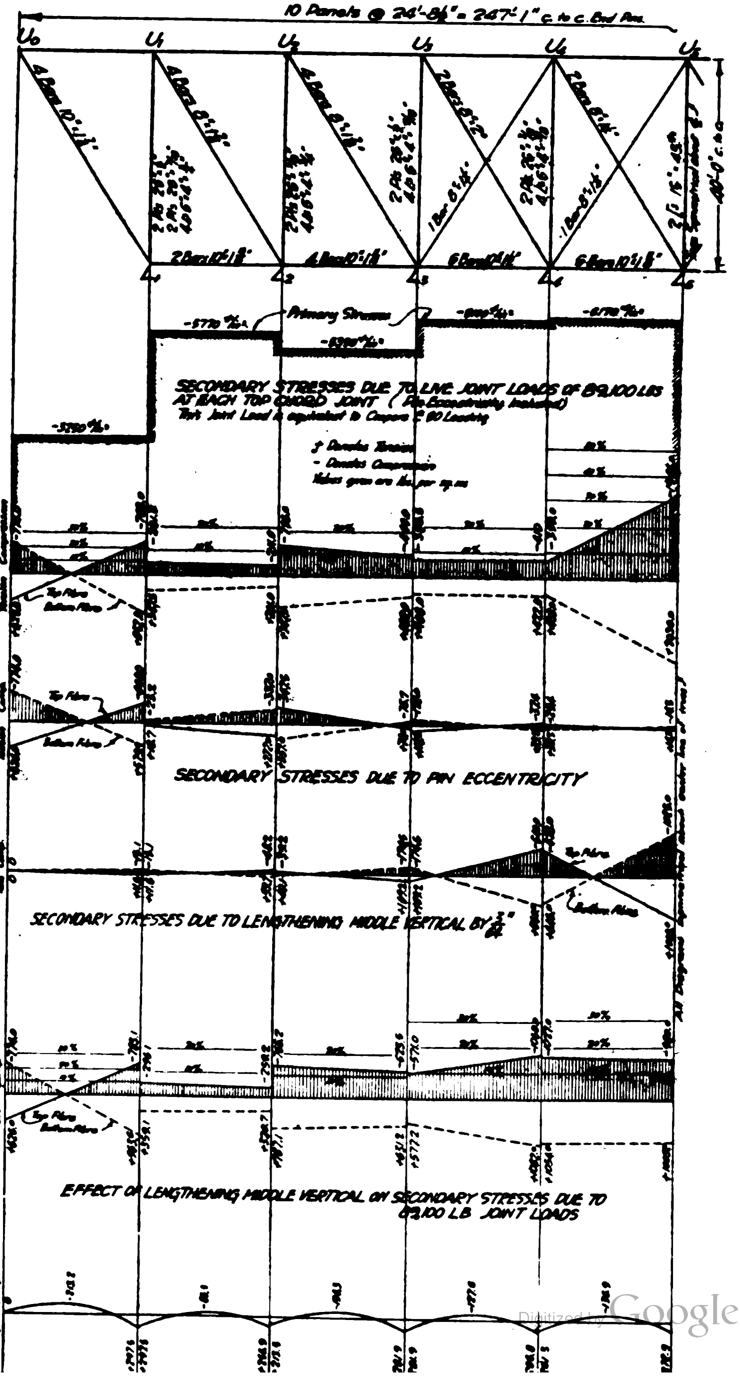
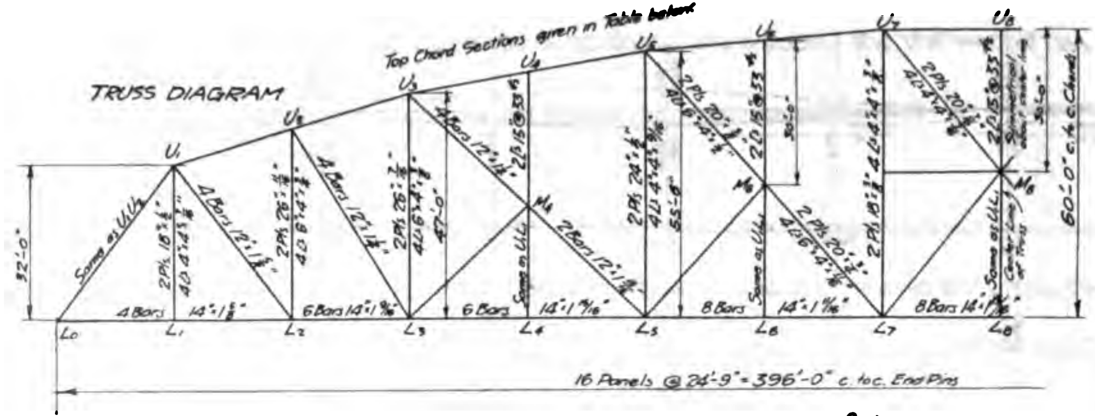


PLATE II-a.

SECONDARY STRESSES IN THE TOP CHORD OF A 396 FT. CURVED CHORD TRUSS



Single Track Structure
Trusses 21'-0" c. to c.

Pin Connected Joints
Riveted Top Chord

Loading; Coopers E-60 Specifications. A.T.&S.F. 1902.
Floor System; Floorbeams and Stringers, Ballast Floor.

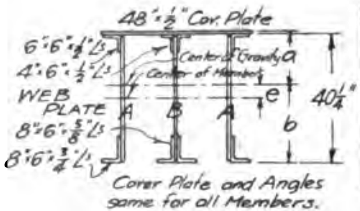


TABLE OF CHORD SECTIONS

Member	Web Pl. "A"	Web Pl. "B"	Area	I	a	b	e
U_1U_2	40×9/16"	40×5/8"	151.6 sq. ins.	37,618 ins.⁴	19.115"	21.635"	1.51"
U_2U_3	40×13/16"	40×5/8"	171.6 "	40,310 "	19.295"	21.455"	1.33"
$U_3U_4U_5$ & U_7U_8	40×9/16" 40×5/8"	40×5/8"	201.6 "	44,370 "	19.490"	21.260"	1.135"
$U_5U_6U_7$	40×9/16" 40×5/8"	40×11/16"	204.1 "	44,973 "	19.505"	21.245"	1.120"

PLATE II-b.

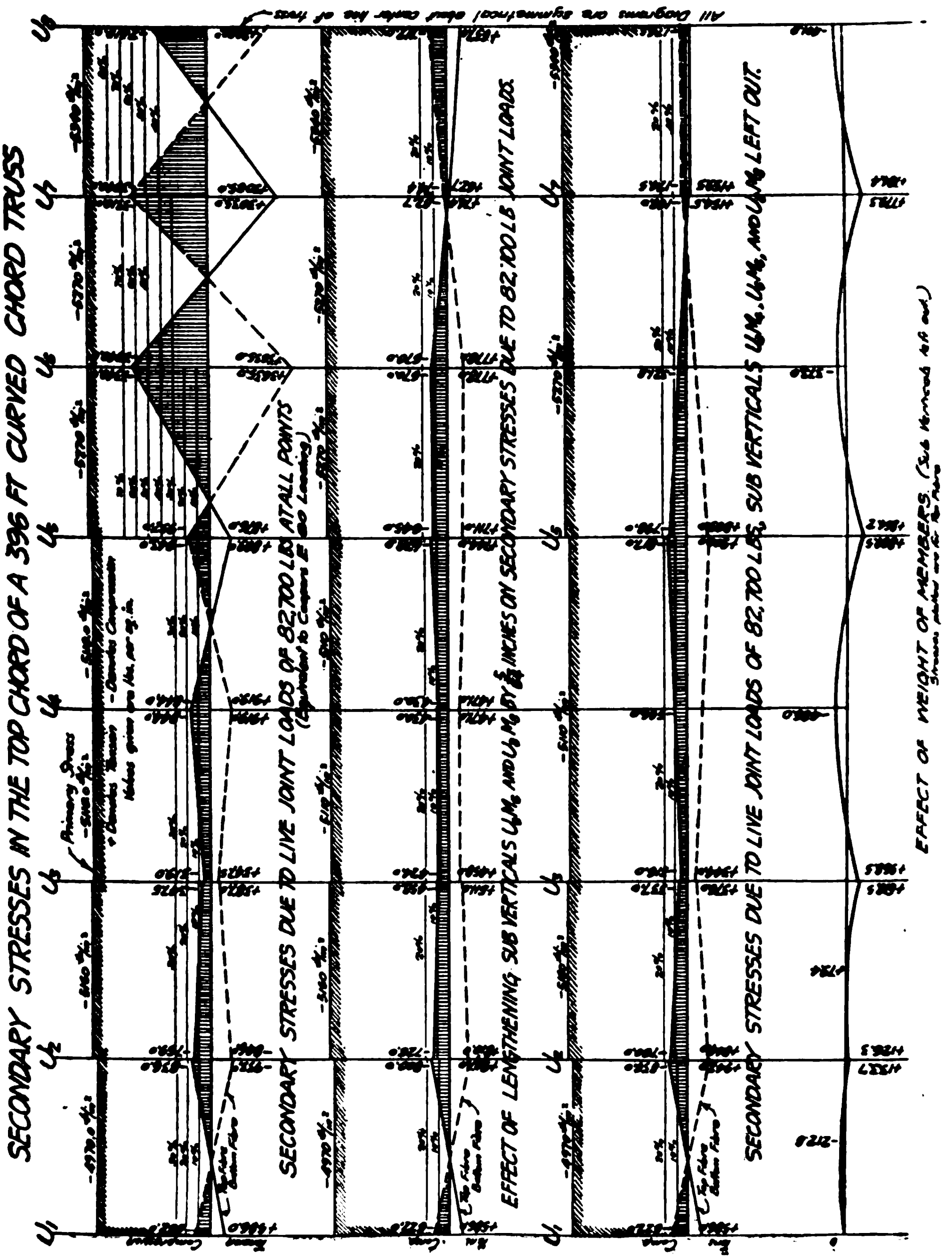
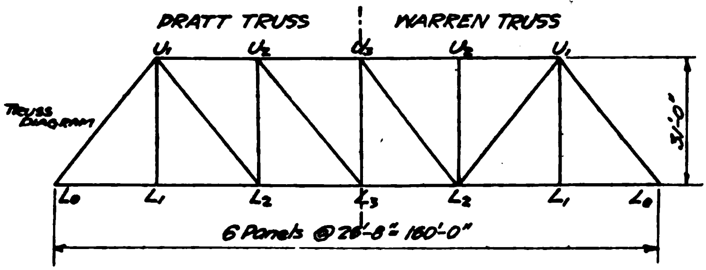

SECONDARY STRESSES IN THE TOP CHORD OF A 396 FT CURVED CHORD TRUSS
All Diagrams are Symmetrical about Center line of truss
SECONDARY STRESSES DUE TO LIVE JOINT LOADS OF 82,700 LBS AT ALL POINTS
EFFECT OF WEIGHT OF MEMBERS.

PLATE III-a.

SECTION TABLE FOR PRATT AND WARREN TRUSS

Taken from the Example given on page 441 Modern Framed Structures Part II



SECTION TABLE

Truss	Member	Section	Area	a	b	I
PRATT AND WARREN	L_0U_1	1 Cov. Pl. 26" × 9/16" 2 Webs 22" × 5/8" 2 Ls 3½" × 3½" × ½" (Top) 2 Ls 5" × 3½" × 5/8" (Bottom)	58.49	9.54"	14.08"	4490
	U_1U_2 U_2U_3	1 Cov. Pl. 26" × 9/16" 2 Webs 22" × 9/16" 2 Ls 3½" × 3½" × 3/8" (Top) 2 Ls 5" × 3½" × ½" (Bottom)	52.35	9.19	14.45	3978
	L_0L_1 L_1L_2	2 Pls 18" × ½" 4 Ls 4" × 4" × 3/8"	29.44	9.12	9.12	1218
	U_1L_1	4 Ls 5" × 3½" × ½"	16.0	5.4	5.4	94.8
	U_1L_2	2 [s 15" @ 50 #s	29.42	7.5	7.5	805.4
PRATT TRUSS	L_2L_3	4 Ls 4" × 4" × 3/8" 2 Pls 18" × ½"	45.48	9.12	9.12	1907
	U_2L_2	2 [s 15" @ 45 #s	26.48	7.5	7.5	750.2
	U_2L_3	2 [s 12" @ 35 #s	20.58	6.0	6.0	358.6
	U_3L_3	2 [s 12" @ 27 #s	14.70	6.0	6.0	288.0
WARREN TRUSS	L_2L_3	4 Ls 4" × 4" × 3/8" 2 Pls 18" × ½"	56.46	9.12	9.12	2370
	U_2L_2	4 Ls 5" × 3½" × ½"	16.0	5.4	5.4	94.8
	U_3L_2	2 [s 15" @ 45 #s	26.48	7.5	7.5	750.2
	U_3L_3	4 Ls 5" × 3½" × ½"	16.0	5.4	5.4	94.8

Note "a" is distance from neutral axis of section to top fibre
"b" " " " " " " " bottom fibre

PLATE III-b.

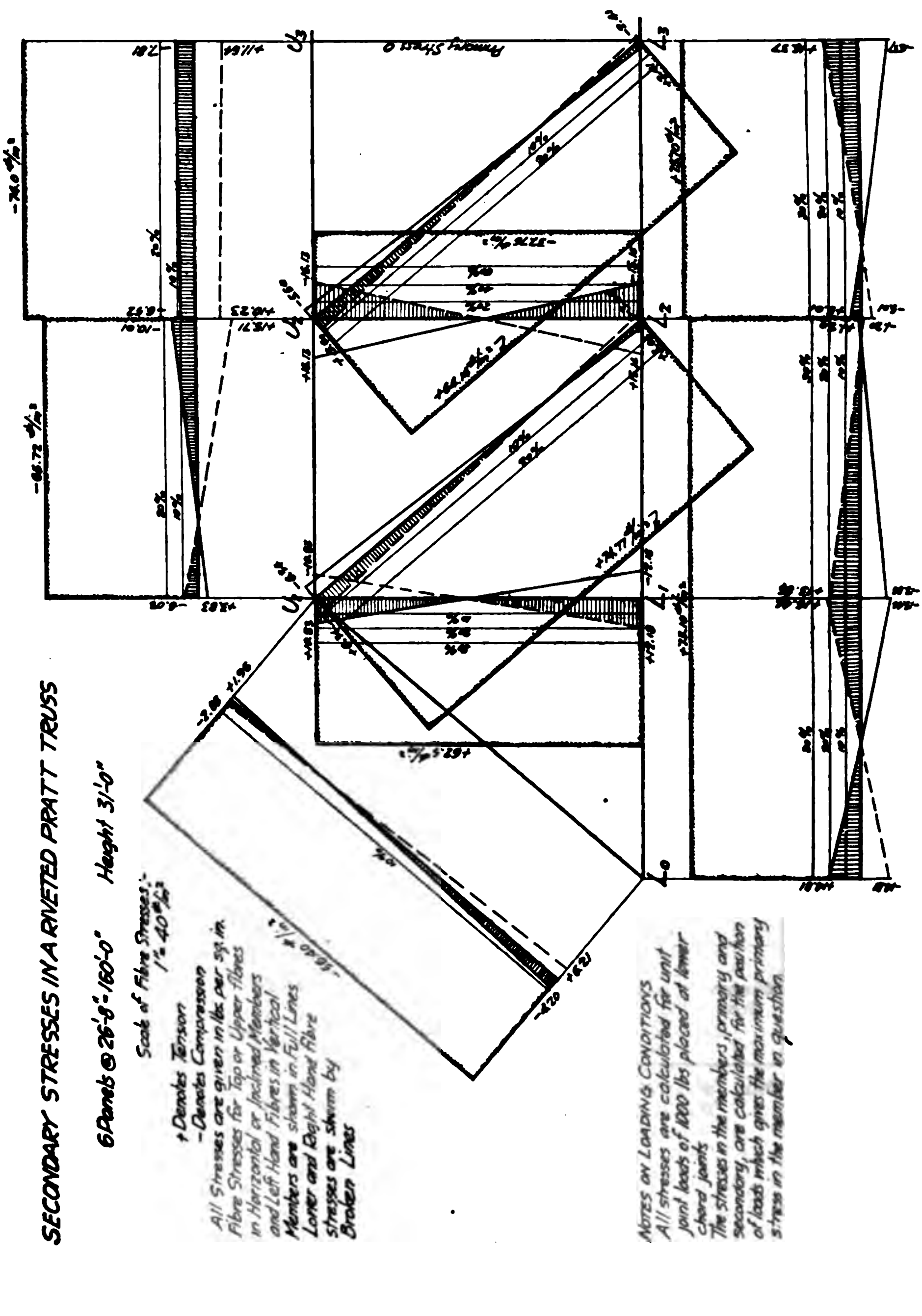

SECONDARY STRESSES IN A RIVETED PRATT TRUSS
6 Panels @ 26'-8" = 160'-0"   Height 31'-0"
Scale of Fibre Stresses: 1" = 40#/□"
+ Denotes Tension
- Denotes Compression
All Stresses are given in lbs. per sq. in. Fibre Stresses for Top or Upper Fibres in Horizontal or Inclined Members and Left Hand Fibres in Vertical Members are shown in Full Lines. Lower and Right Hand Fibre stresses are shown by Broken Lines
NOTES ON LOADING CONDITIONS
All stresses are calculated for unit joint loads of 1000 lbs placed at lower chord joints.
The stresses in the members, primary and secondary, are calculated for the position of loads which gives the maximum primary stress in the member in question.
Primary Stress 0
U1
U2
U3
L0
L1
L2
L3

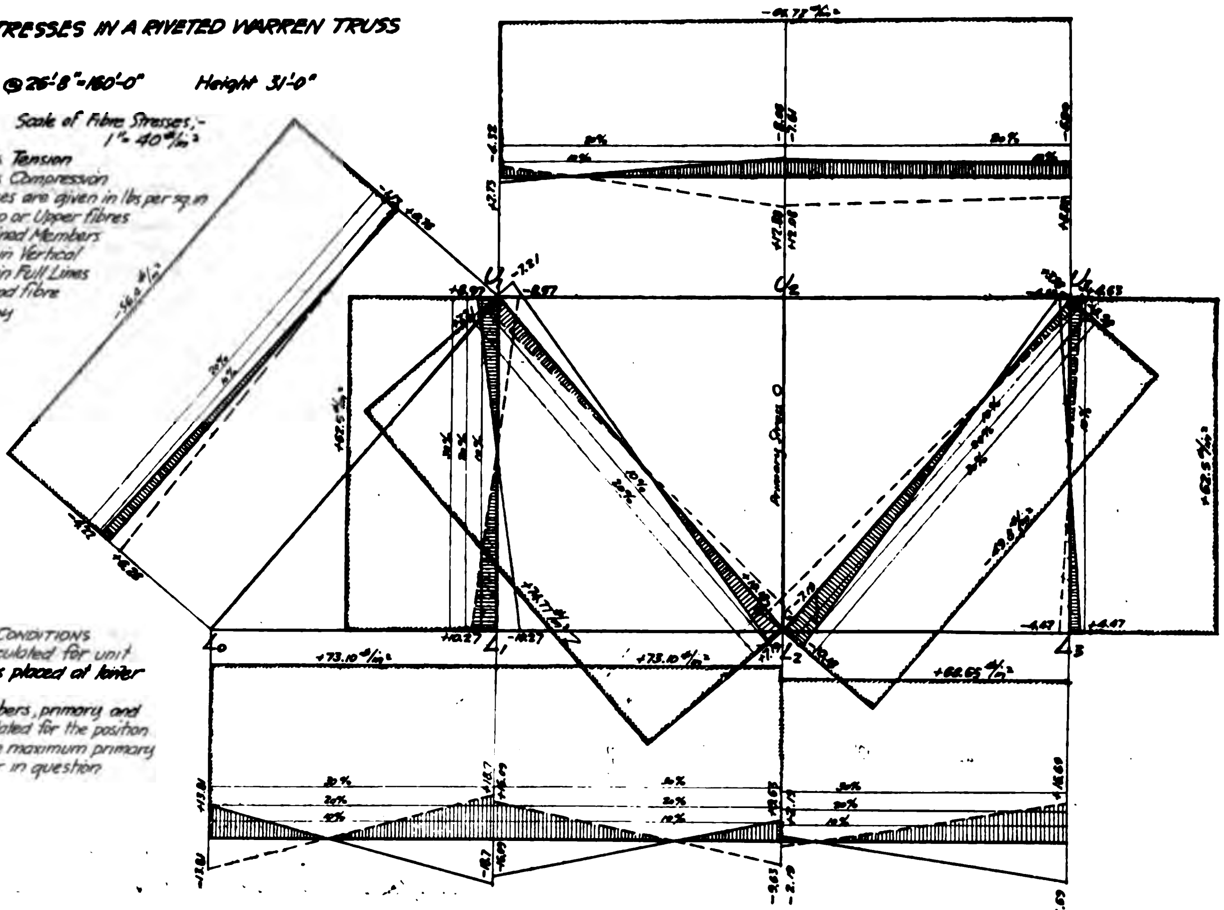
PLATE III-c.

SECONDARY STRESSES IN A RIVETED WARREN TRUSS

6 Panels @ 26'-8" = 160'-0"   Height 31'-0"

Scale of Fibre Stresses;- 1" = 40#/in²

+ Denotes Tension
- Denotes Compression
All stresses are given in lbs per sq in
Fibre Stresses for Top or Upper fibres in Horizontal or Inclined Members and Left Hand Fibres in Vertical Members are shown in Full Lines
Lower and Right Hand fibre stresses are shown by Broken Lines



NOTES ON LOADING CONDITIONS
All stresses are calculated for unit joint loads of 1000 lbs placed at lower chord joints
The stresses in the members, primary and secondary, are calculated for the position of loads which gives the maximum primary stress in the member in question

PLATE IV-a.

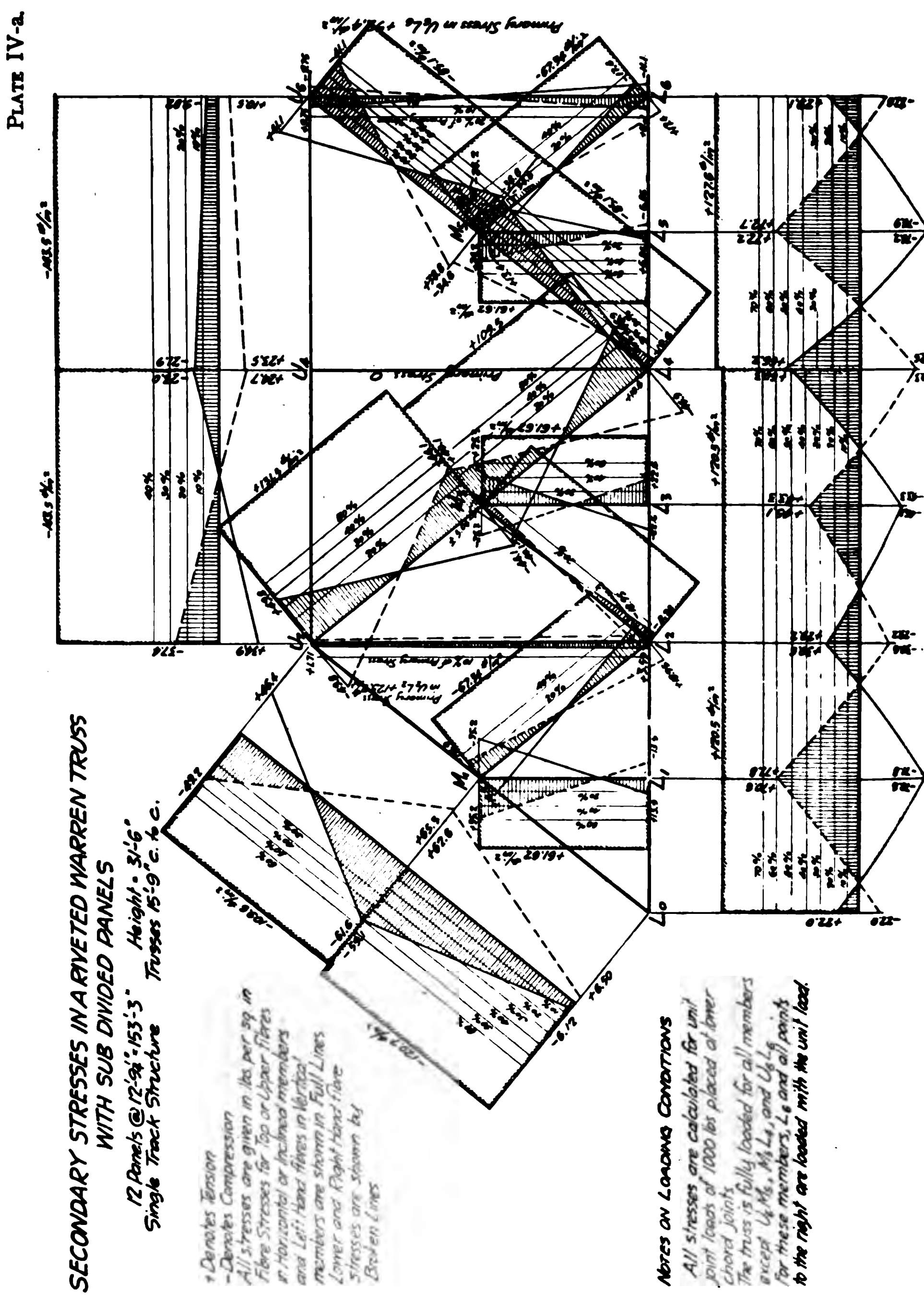
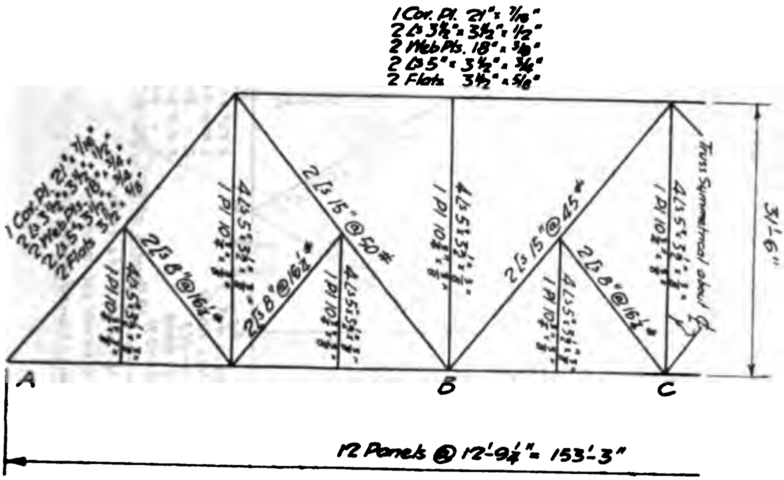
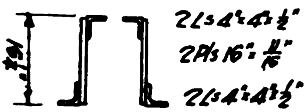

SECONDARY STRESSES IN A RIVETED WARREN TRUSS
WITH SUB DIVIDED PANELS
12 Panels @ 12'-9¼" = 153'-3"   Height = 31'-6"
Single Track Structure   Trusses 15'-9" c. to c.
+ Denotes Tension
− Denotes Compression
All stresses are given in lbs per sq. in
Fibre Stresses for Top or Upper fibres
in Horizontal or Inclined members
and Left Hand fibres in Vertical
members are shown in Full Lines
Lower and Right Hand fibre
stresses are shown by
Broken Lines
NOTES ON LOADING CONDITIONS
All stresses are calculated for unit
joint loads of 1000 lbs placed at lower
chord joints.
The truss is fully loaded for all members
except U_6M_5, M_5L_4, and U_6L_6
For these members, L_6 and all points
to the right are loaded with the unit load.
L_0
L_1
L_2
L_3
L_4
L_5
L_6
U_2
U_4
U_6
M_1
M_3
M_5

PLATE IV-b.

DIAGRAM OF SECTIONS
RIVETED WARREN TRUSS WITH SUB-DIVIDED PANELS



BOTTOM CHORD A to B



BOTTOM CHORD B to C

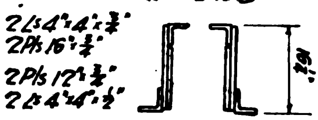


PLATE IV-c.

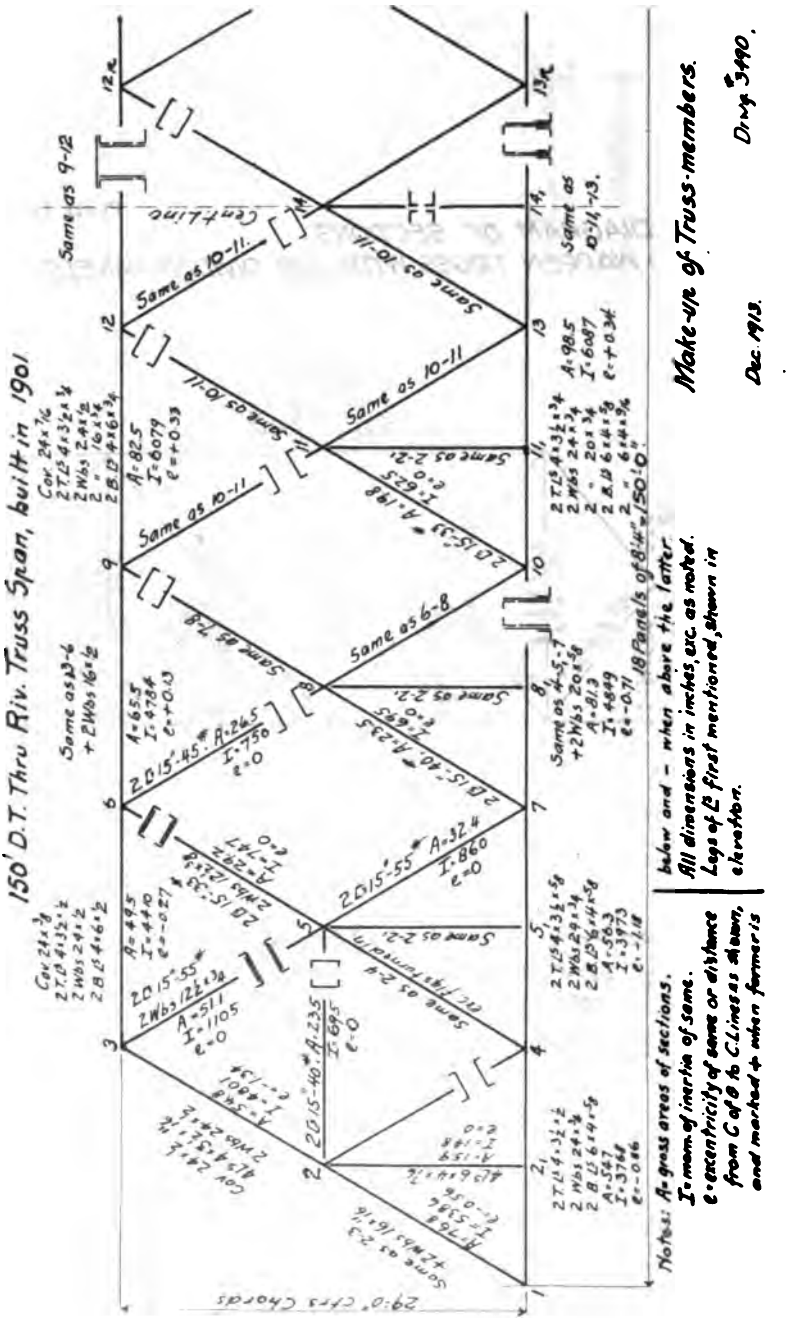
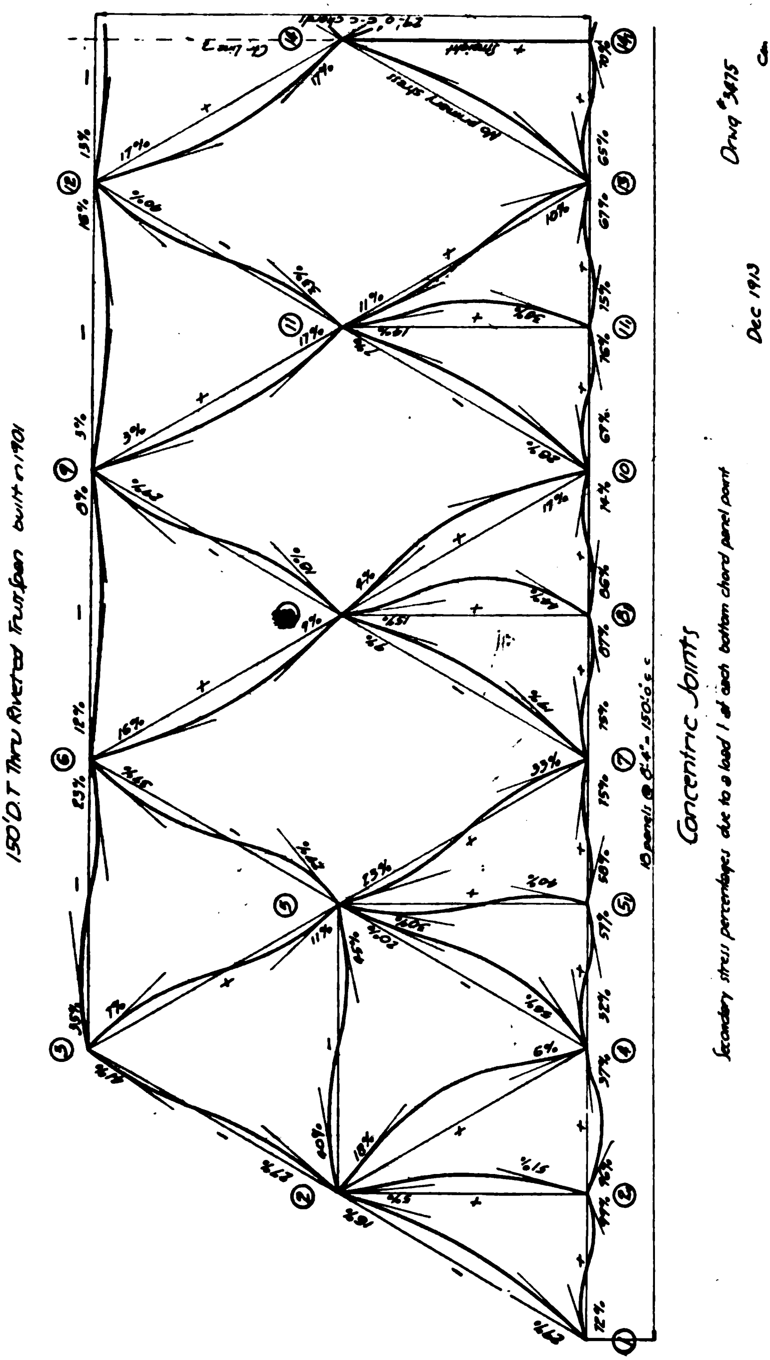
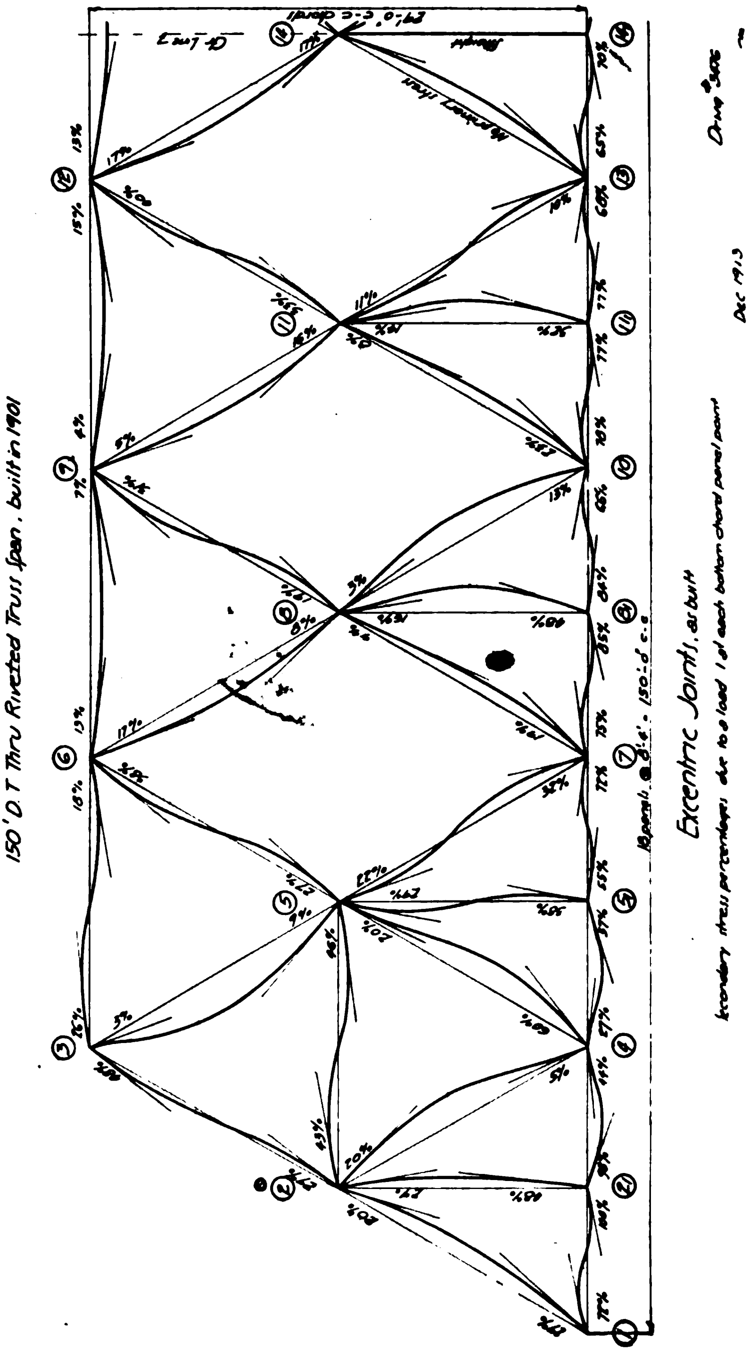

150' D.T. Thru Riv. Truss Span, built in 1901
Make-up of Truss-members.
Dec. 1913.
Drwg. # 3490.
Center Line
18 Panels of 8'4" = 150'0"
29'0" c/c's Chords
Notes: A= gross areas of sections.
I= mom. of inertia of same.
e= eccentricity of same or distance from C of G to C. Lines as shown, and marked + when former is below and − when above the latter.
All dimensions in inches, exc. as noted.
Legs of L^s first mentioned, shown in elevation.

PLATE IV-d.



SECONDARY STRESSES IN A SUB-DIVIDED DOUBLE TRIANGULAR TRUSS.

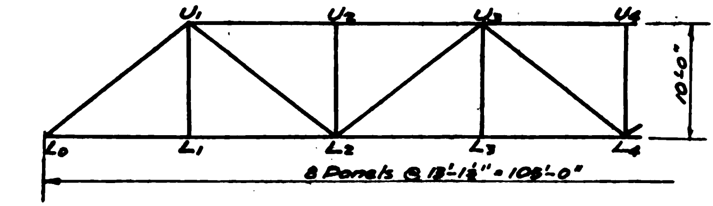
PLATE IV-c.



SECONDARY STRESSES IN A SUB-DIVIDED DOUBLE TRIANGULAR TRUSS.

PLATE V-a.

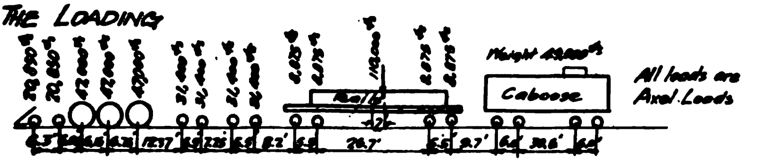
105 FT. RIVETED PONY WARREN TRUSS



SECTION TABLE

Member	Section	c	Area	I
L_0L_1 & L_1L_2	4 Ls 4"×4"×3/8"; 2 Pls 18"×1/2"	9.25"	29.44	1254.4
L_2L_3 & L_3L_4	4 Ls 4"×4"×5/8"; 2 Pls 18"×5/8"; 2 Pls 10"×1/2"	9.25"	55.98	1947.6
L_0U_1	4 Ls 4"×4"×5/8", 2 Pls 20"×5/8"	10.25"	43.48	2364.6
U_1U_2 & U_2U_3	4 Ls 4"×4"×5/8"; 2 Pls 20"×5/8"	10.25"	43.48	2364.6
U_3U_4	4 Ls 4"×4"×5/8"; 2 Pls 20"×5/8"; 2 Pls 12"×1/2"	10.25"	55.48	2508.6
U_1L_1 & U_3L_3	4 Ls 5"×3½"×3/8"; 1 Pl 13½"×3/8"; 1 Pl 10½"×3/8"	5.25"	22.99	124.0
U_2L_2 & U_4L_4	4 Ls 5"×3½"×3/8"; 1 Pl 13½"×3/8"	5.75"	17.24	73.0
U_1L_2	4 Ls 6"×4"×5/8"; 1 Pl 13½"×5/8"	6.25"	28.48	206.0
U_3L_2	4 Ls 6"×4"×9/16"; 1 Pl 13½"×5/8"	6.25"	26.28	185.4
U_3L_4	4 Ls 6"×4"×3/8"; 1 Pl 13½"×3/8"	6.25"	19.48	123.0

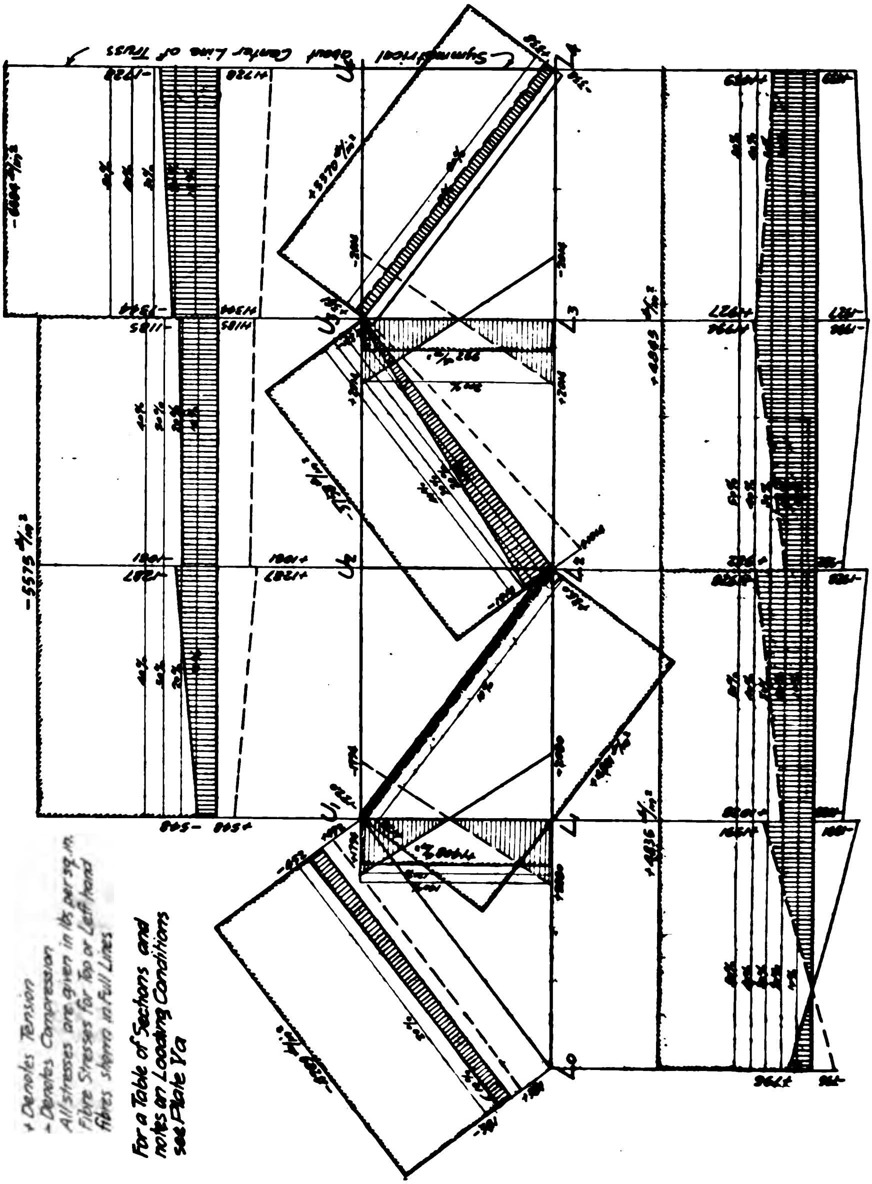
THE LOADING



LOADING CONDITIONS. For the calculated values, shown on Plate V b the train loads are placed in the position which gives the maximum combined value of primary and secondary stresses. This position of loading is determined by the use of Influence Lines drawn for each member.

The observed values, given on Plate V c were obtained from extensiometer readings taken on the structure for a test train as shown by the train diagram above.

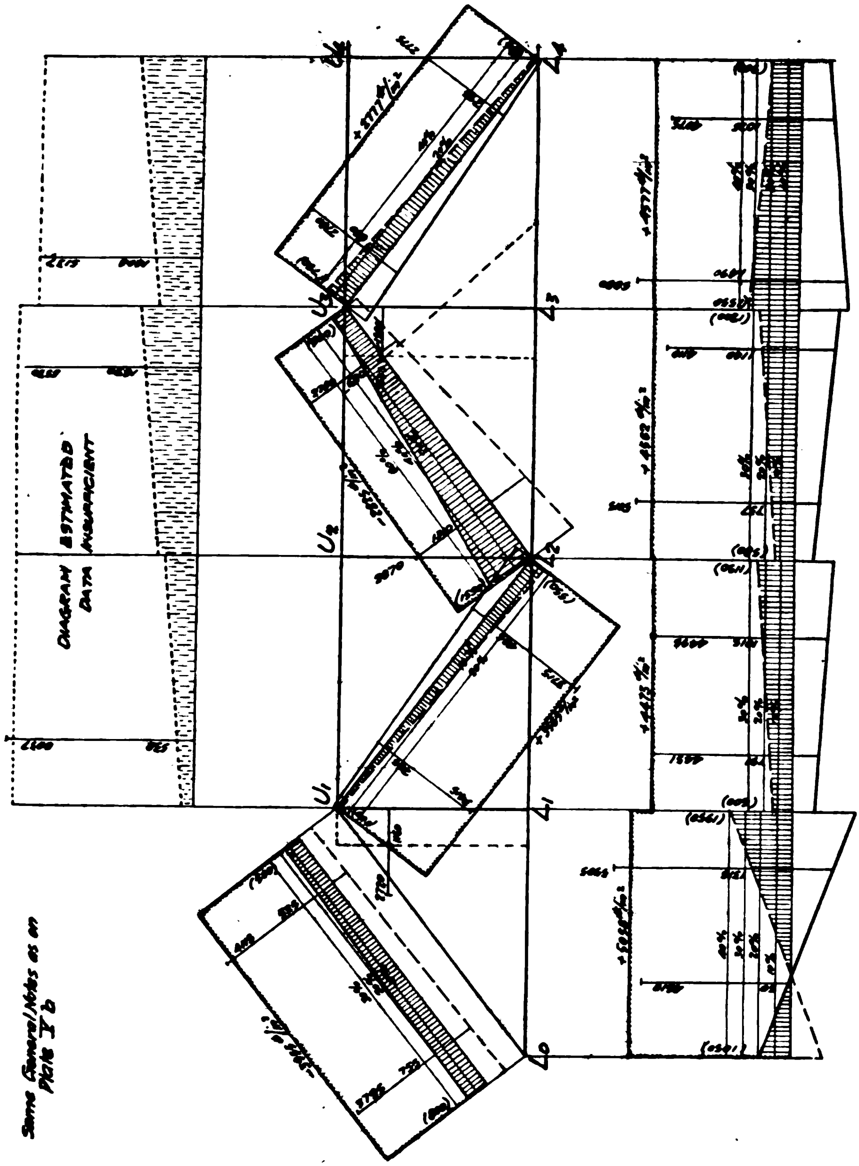
PLATE V-b.



CALCULATED SECONDARY STRESSES IN A 105 FT. RIVETED PONY WARREN TRUSS

PLATE V-c.

OBSERVED SECONDARY STRESSES IN A 105 FT. RIVETED PONY WARREN TRUSS



Note:- Values shown in brackets, thus (800), are estimated by scaling

PLATE VI.

SECONDARY STRESSES IN A VIADUCT TOWER

POST SECTIONS

MEMBERS 1-3 AND 3-5
4 Ls 6" × 6" × 3/4"
2 Pls 26" × 5/8"
2 Pls 26" × 1/2"
Area of Section 95.5 sq. ins

MEMBERS 5-7 AND 7-9
4 Ls 6" × 6" × 3/4"
2 Pls 26" × 5/8"
Area of Section 82.5 sq. ins

The Web Plates are placed parallel to Center line of Viaduct

+ Denotes Tension
− Denotes Compression
All stresses are given in lbs per sq. in.
The stresses, primary and secondary, are calculated for a load of 1000 lbs. assumed as acting along the axis of the column section.

Fibre stresses for Outside fibres shown in Full Lines. Inside fibre stresses shown in Broken Lines

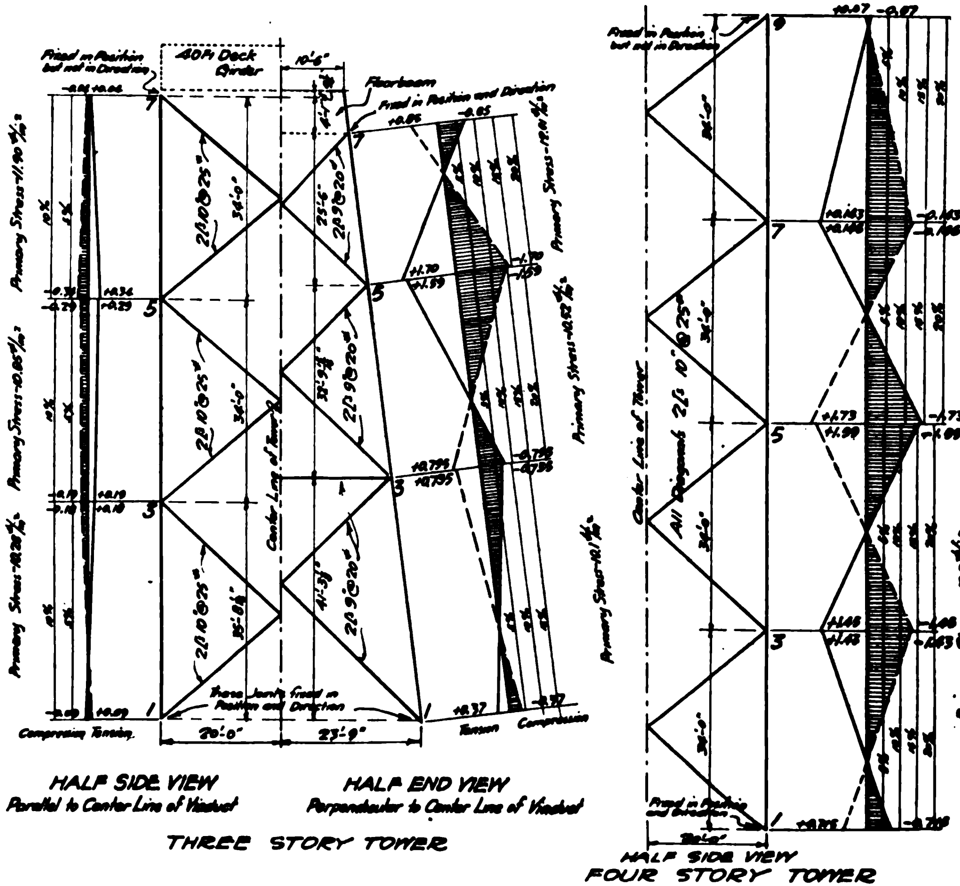


PLATE VII-a.

TRUSS DIAGRAMS

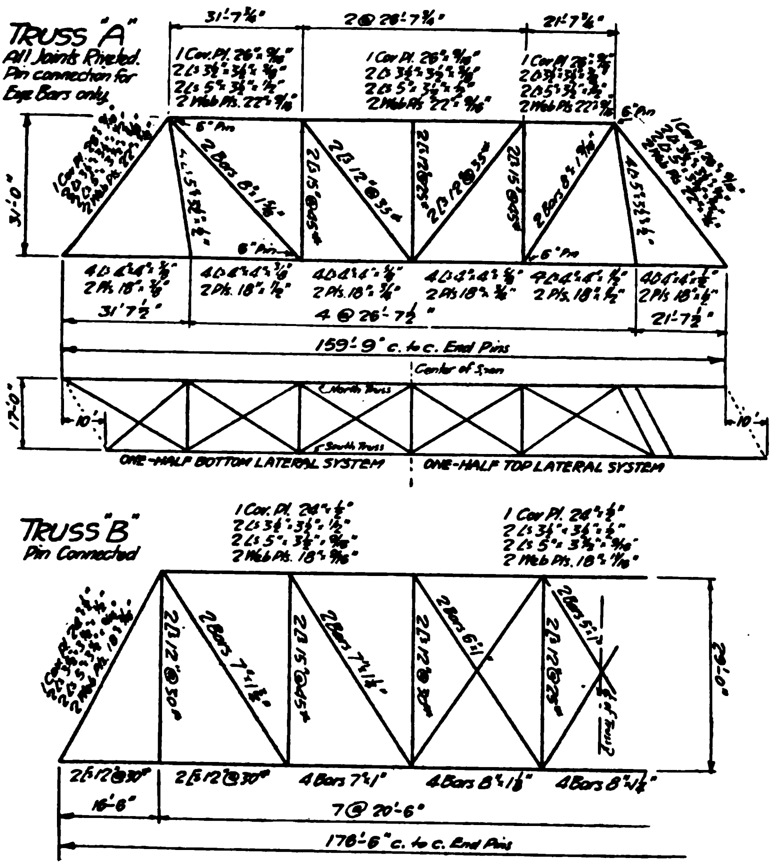
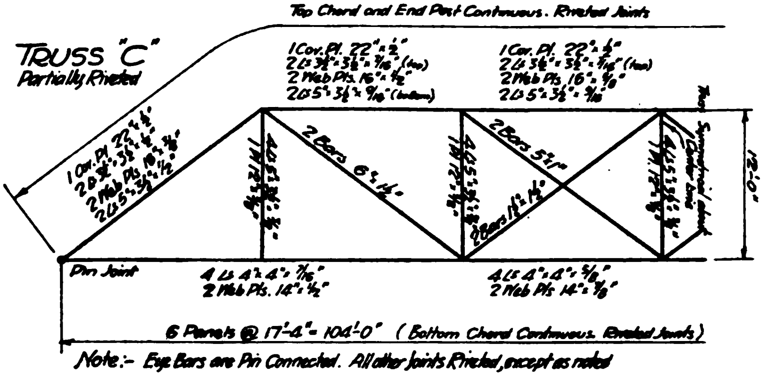


PLATE VII-b.

TRUSS DIAGRAMS



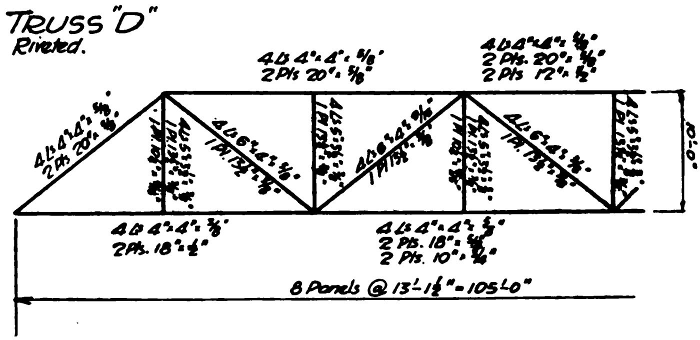
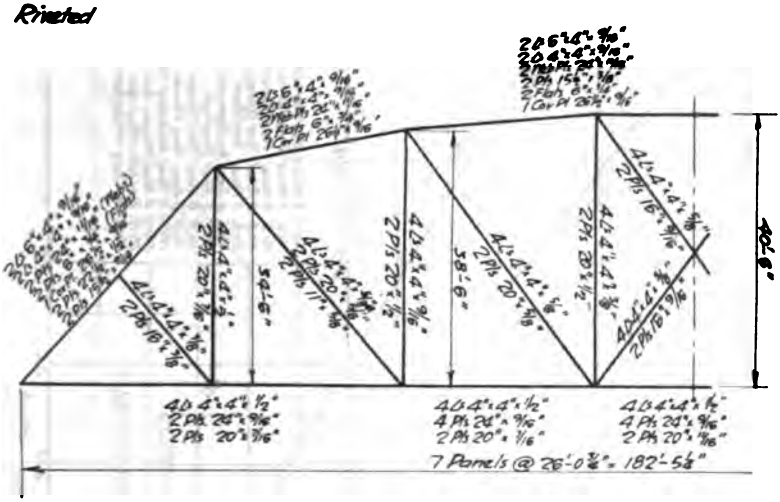


PLATE VII-c.

TRUSS DIAGRAMS

TRUSS "E"
Riveted



TRUSS "F"
Pin Connected

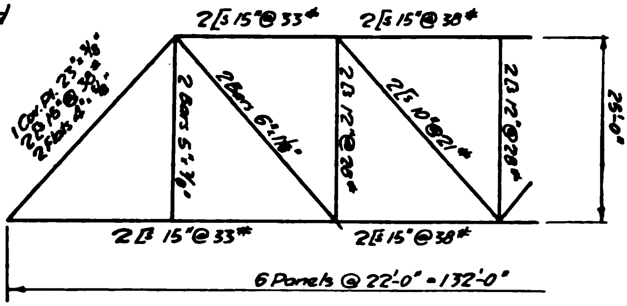


PLATE VIII-a.

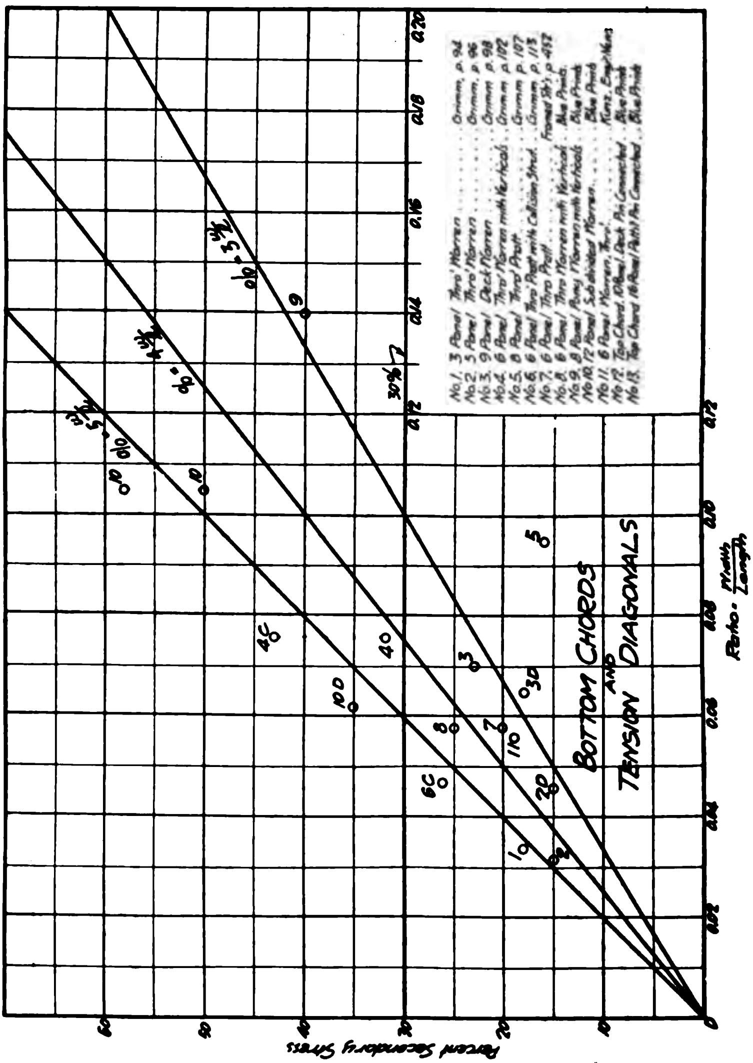

No. 1. 3 Panel Thro' Warren . . . Grimm, p. 94
No. 2. 5 Panel Thro' Warren . . . Grimm, p. 96
No. 3. 9 Panel Deck Warren . . . Grimm, p. 98
No. 4. 6 Panel Thro' Warren with Verticals . . Grimm, p. 102
No. 5. 8 Panel Thro' Pratt . . . Grimm, p. 107
No. 6. 6 Panel Thro' Pratt with Collision Strut . . Grimm, p. 113
No. 7. 6 Panel Thro Pratt . . . Framed Str's, p. 457
No. 8. 6 Panel Thro Warren with Verticals . . Blue Prints
No. 9. 8 Panel Pony Warren with Verticals . . Blue Prints
No. 10. 12 Panel Subdivided Warren . . . Blue Prints
No. 11. 6 Panel Warren, Thro' . . . Kunz, Eng'g News
No. 12. Top Chord. 10 Panel Deck Pin Connected . . Blue Prints
No. 13. Top Chord 16 Panel Pettit Pin Connected . . Blue Prints
BOTTOM CHORDS AND TENSION DIAGONALS
Percent Secondary Stress
Ratio = Width / Length

PLATE VIII-b.

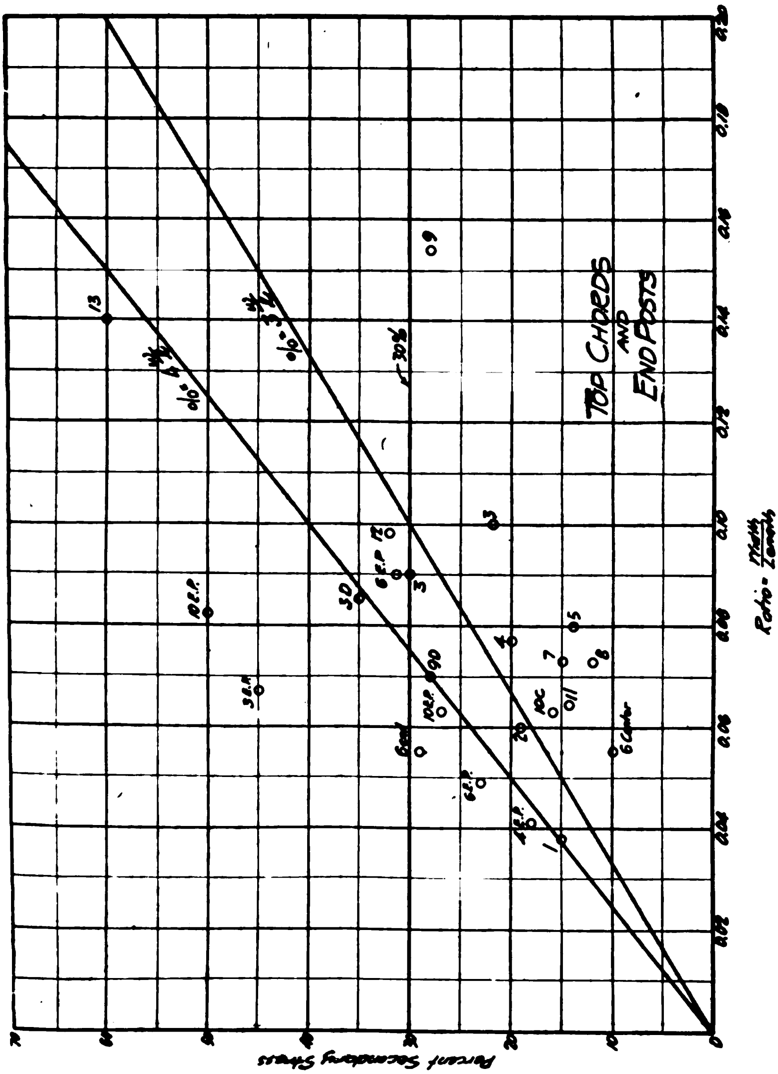
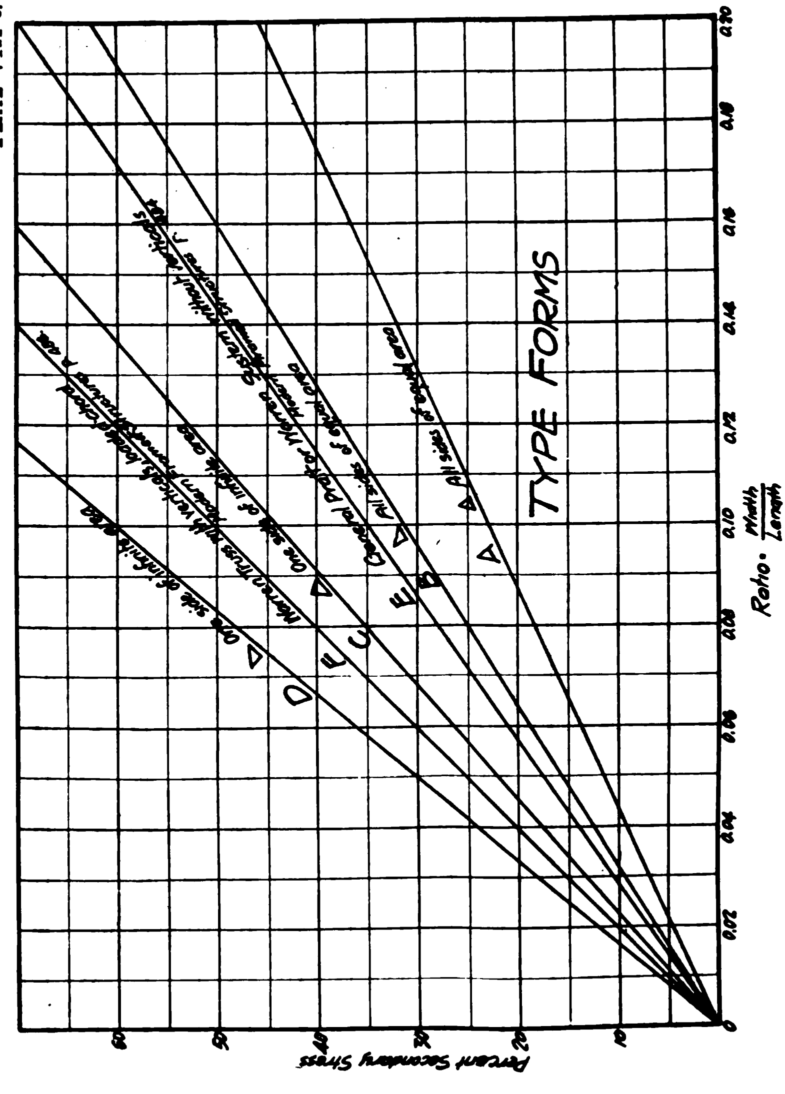
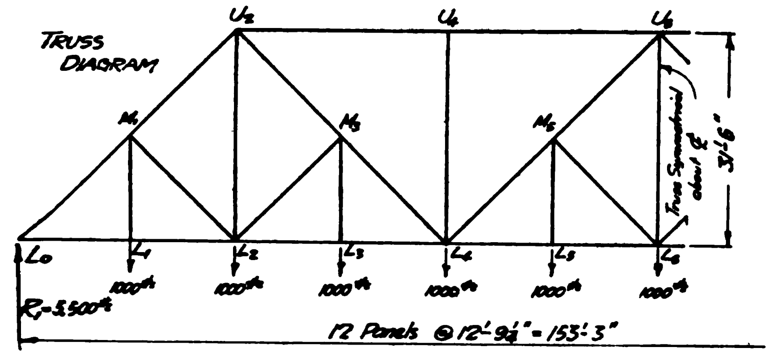

TOP CHORDS AND END POSTS
Percent Secondary Stress
Ratio = Width/Length

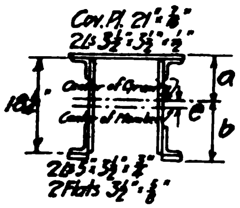
PLATE VIII-C.


TYPE FORMS
A
B
C
D
E
F
All sides of equal area
One side of infinite area
Ratio = Width / Length
Percent Secondary Stress
0
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
10
20
30
40
50
60

SECONDARY STRESSES IN A RIVETED WARREN TRUSS WITH SUB DIVIDED PANELS

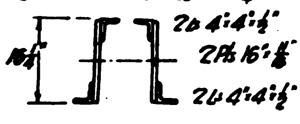


CHORD SECTIONS



	TOP CHORD	END POST
WEB PLATE	18" x 3/8"	18" x 1/4"
a	9.3195"	9.375"
b	9.993"	9.9375"
e	0.243"	0.1875"

BOTTOM CHORD L_0 to L_4



BOTTOM CHORD L_4 to L_6

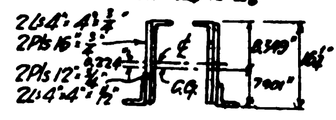
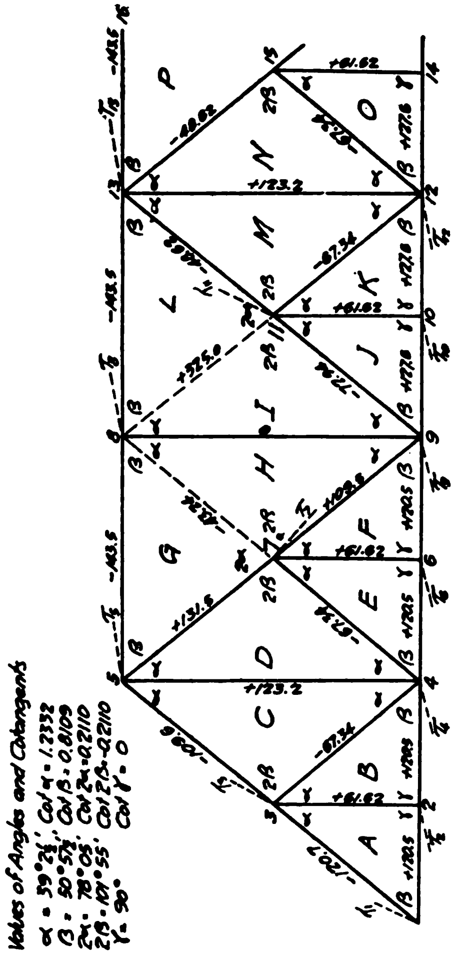


TABLE A

TABLE OF SECTIONS

MEMBER		SECTION	LENGTH (ins)	I (ins⁴)	$K = \frac{I}{l}$	c (ins)	$2c/l$	STRESS (#s)	AREA (sq. ins)	UNIT STRESS (#/in²)
U_2U_4 U_4U_6	5-8 8-13	TOP CHORD See Page 1	306.5	2644.5	8.63	T 9.3195 B 9.993	0.0608 0.0652	-6,487	45.20	-143.5
L_0L_1 L_1L_2 L_2L_3 L_3L_4	1-2 2-4 4-6 6-9	BOTTOM CHORD See page 1	153.25	1214.6	7.93	8.125	0.1060	+4,460	37.00	+120.5
L_4L_5 L_5L_6	9-10 10-12	"	153.25	1696.4	11.07	T 8.349 B 7.901	0.1089 0.1030	+7,704	60.38	+127.6
L_0M_1	1-3	END POST See page 1	243.3	3009.4	12.37	T 9.375 B 9.9375	0.0770 0.0816	-7,080.5	58.70	-120.7
M_1U_2	3-5	"	243.3	3009.4	12.37	T 9.375 B 9.9375	0.0770 0.0816	-6,437.5	58.70	-109.6
U_2M_3	5-7	2 [s 15" @ 50#	243.3	805.4	3.31	7.5	0.0617	+3864	29.42	+131.5
M_3L_4	7-9	2 [s 15" @ 50#	243.3	805.4	3.31	7.5	0.0617	+3220	29.42	+109.5
L_4M_5	9-11	2 [s 15" @ 45#	243.3	750.2	3.08	7.5	0.0617	-1931.4	26.48	-72.94
M_5U_6	11-13	2 [s 15" @ 45#	243.3	750.2	3.08	7.5	0.0617	-1287.5	26.48	-48.62
M_1L_2 M_3L_2 M_5L_6	3-4 4-7 11-12	2 [s 8" @ 16¼#	243.3	79.8	0.328	4.0	0.0329	-643.75	9.56	-67.34
M_1L_1 M_3L_3 M_5L_5	3-2 7-6 11-10	4 ∠s 5"×3½"×⅜" 1 Pl. 10½"×⅜"	189.0	70.7	0.374	5.1875	0.0548	+1000	16.23	+61.62
U_2L_2 U_6L_6	5-4 13-12	4 ∠s 5"×3½"×⅜" 1 Pl. 10½"×⅜"	378.0	70.7	0.187	5.1875	0.0274	+2000	16.23	+123.2
U_4L_4	8-9	4 ∠s 5"×3½"×⅜" 1 Pl. 10½"×⅜"	378.0	70.7	0.187	5.1875	0.0274	0	16.23	0

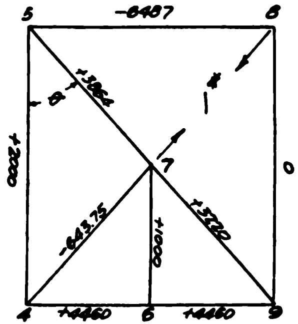
Stresses are for 1000# Joint Loads at all bottom chord points
+ Denotes Tension — Denotes Compression
"T" and "B" denote Top and Bottom Fibre of Section



+ Denotes Tension − Denotes Compression
All stresses are given in pounds per square inch.

UNIT STRESS DIAGRAM

Distortion on Line 7-8



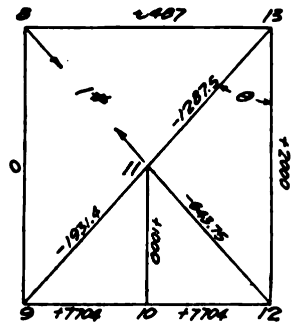
$\sin\theta = 0.6299$
$\cos\theta = 0.7768$

Member	Stress	Area	p	l	u	plu
5-8	-6487	45.20	-143.5	306.5	-0.6299	+27,705
8-9	0	16.23	0	378.0	-0.7768	0
4-6-9	+4460	37.00	+120.5	306.5	-0.6299	-23,265
4-5	+2000	16.23	+123.2	378.0	-0.7768	-36,175
5-7	+3864	29.42	+131.5	243.3	+1.0	+31,995
7-9	+3220	29.42	+109.5	243.3	+1.0	+26,642
4-7	-643.75	9.56	-67.34	243.3	+1.0	-16,383

$\Sigma plu = +10,519$

$S_{7-8} = \dfrac{+10,519}{243.3} = 43.24$ compression

Distortion on Line 8-11



Member	Stress	Area	p	l	u	plu
8-13	-6487	45.20	-143.5	306.5	-0.6299	+27,702
13-12	+2000	16.23	+123.2	378.0	-0.7768	-36,175
9-10-12	+7704	60.38	+127.6	306.5	-0.6299	-24,635
9-8	0	16.23	0	378.0	-0.7768	0
13-11	-1287.5	26.48	-48.62	243.3	+1.0	-11,828
11-9	-1931.4	26.48	-72.94	243.3	+1.0	-17,745
11-12	-643.75	9.56	-67.34	243.3	+1.0	-16,383

$\Sigma plu = -79,064$

$S_{8-11} = \dfrac{-79,064}{243.3} = 325.0$ tension

TABLE B

VALUES OF δL

Triangle A	δL 123 = (−120.7 − 61.62)1.233 + (−120.7 − 120.5)0.8109	= −420.5
	δL 231 = (+120.5 + 120.7)0.8109	= +195.6
	δL 312 = (+61.62 + 120.7)1.233	= +225.0
Triangle B	δL 324 = (−67.34 − 61.62)1.233 + (−67.34 − 120.5)0.8109	= −311.2
	δL 243 = (+61.62 + 67.34)1.233	= +159.0
	δL 432 = (+120.5 + 67.34)0.8109	= +152.2
Triangle C	δL 534 = (+123.2 + 67.34)1.233 + (+123.2 + 109.6)1.233	= +523.0
	δL 345 = (−109.6 − 123.2)1.233 − (−109.6 + 67.34)0.2110	= −278.1
	δL 453 = (+67.34 − 109.6)0.2110 + (−67.34 − 123.2)1.233	= −243.9
Triangle D	δL 547 = (+131.5 − 123.2)1.233 + (−131.5 − 67.34)0.2110	= − 31.7
	δL 475 = (+123.2 + 67.34)1.233 + (+123.2 − 131.5)1.233	= +224.8
	δL 754 = (+67.34 + 131.5)0.2110 + (−67.34 − 123.2)1.233	= −193.1
Triangle E	δL 746 = (+61.62 + 67.34)1.233	= +159.0
	δL 467 = (−67.34 − 61.62)1.233 + (−67.34 − 120.5)0.8109	= −311.2
	δL 674 = (+120.5 + 67.34)0.8109	= +152.2
Triangle F	δL 976 = (+120.5 − 109.5)0.8109	= + 8.9
	δL 769 = (+109.5 − 61.62)1.233 + (+109.5 − 120.5)0.8109	= + 37.9
	δL 697 = (+61.62 − 109.5)1.233	= − 46.8
Triangle G	δL 857 = (−43.24 − 131.5)0.2110 + (−43.24 + 143.5)0.8109	= + 44.6
	δL 578 = (−143.5 + 43.24)0.8109 + (−143.5 − 131.5)0.8109	= −304.5
	δL 785 = (+131.5 + 143.5)0.8109 + (+131.5 + 43.2°)0.2110	= +259.9
Triangle H	δL 879 = (0 − 109.5)1.233 + (0 + 43.24)1.233	= − 81.8
	δL 798 = (−43.24 − 0)1.233 + (+43.24 + 109.5)0.2110	= − 21.2
	δL 987 = (−109.5 − 43.24)0.2110 + (+109.5 − 0)1.233	= +103.1
Triangle I	δL 11·8·9 = (+72.94 + 325.0)0.2110 + (−72.94 − 0)1.233	= − 5.9
	δL 8·9·11 = (+325.0 + 0)1.233 − (+325.0 + 72.94)0.2110	= +318.0
	δL 9·11·8 = (0 + 72.94)1.233 + (0 − 325.0)1.233	= −312.0
Triangle J	δL 11·9·10 = (+61.62 + 72.94)1.233	= +166.1
	δL 9·10·11 = (−72.94 − 61.62)1.233 + (−72.94 − 127.6)0.8109	= −328.6
	δL 10·11·9 = (+127.6 + 72.94)0.8109	= +162.5
Triangle K	δL 11·10·12 = (−67.34 − 61.62)1.233 + (−67.34 − 127.6)0.8109	= −317.0
	δL 10·12·11 = (+61.62 + 67.34)1.233	= +159.0
	δL 12·11·10 = (+127.6 + 67.34)0.8109	= +158.0
Triangle L	δL 13·8·11 = (−48.62 − 325.0)0.2110 + (−48.62 + 143.5)0.8109	= − .1.9
	δL 8·11·13 = (−143.5 + 48.62)0.8109 + (−143.5 − 325.0)0.8109	= −456.0
	δL 11·13·8 = (+325.0 + 143.5)0.8109 + (+325.0 + 48.62)0.2110	= +458.9
Triangle M	δL 13·11·12 = (+123.2 + 67.34)1.233 + (+123.2 + 48.62)1.233	= +447.0
	δL 11·12·13 = (−48.62 − 123.2)1.233 + (+48.62 − 67.34)0.2110	= −215.9
	δL 12·13·11 = (+67.34 − 48.62)0.2110 + (−67.34 − 123.2)1.233	= −231.1

Triangle N same as Triangle M Triangle O same as Triangle K

Triangle P same as Triangle L

TABLE C
VALUES OF $\Sigma\delta L$ AND $K\Sigma\delta L$

Joint (1)	L (2)	δL (3)	$\Sigma\delta L$ (4)	Member (5)	K (6)	$K\Sigma\delta L$ (7)
1	3·1·2	+225.0	+225.0	1-3 1-2	12.37 7.93 20.30	+ 1,784.0 + 1,784.0
2	1·2·3 3·2·4	−420.5 −311.2	−420.5 −731.7	2-1 2-3 2-4	7.93 0.374 7.93 16.23	− 157.3 − 5,803.0 − 5,960.3
3	5·3·4 4·3·2 2·3·1	+523.0 +152.2 +195.5	+523.0 +675.2 +870.7	3-5 3-4 3-2 3-1	12.37 0.328 0.374 12.37 25.44	+ 171.5 + 252.5 +10,770.0 +11194.0
4	2·4·3 3·4·5 5·4·7 7·4·6	+159.0 −278.1 − 31.7 +159.0	+159.0 −119.1 −150.8 + 8.2	4-2 4-3 4-5 4-7 4-6	7.93 0.328 0.187 0.328 7.93 16.70	+ 52.2 − 22.3 − 49.5 + 65.0 + 45.4
5	8·5·7 7·5·4 4·5·3	+ 44.6 −193.1 −243.9	+ 44.6 −148.5 −392.4	5-8 5-7 5-4 5-3	8.63 3.31 0.187 12.37 24.50	+ 147.6 − 27.8 − 4,854.2 − 4,734.4
6	4·6·7 7·6·9	−311.2 + 37.9	−311.2 −273.3	6-4 6-7 6-9	7.93 0.374 7.93 16.23	− 116.4 − 2,167.2 − 2,283.6
7	9·7·6 6·7·4 4·7·5 5·7·8	+ 8.9 +152.2 +224.8 −304.5	+ 8.9 +161.1 +385.9 + 81.4	7-9 7-6 7-4 7-5 7-8	3.31 0.374 0.328 3.31 0 7.32	+ 3.33 + 52.8 + 1277.2 0 + 1333.3
8	13·8·11 11·8·9 9·8·7 7·8·5	− 1.9 − 5.9 +103.1 +259.9	− 1.9 − 7.8 + 95.3 +355.2	8-13 8-11 8-9 8-7 8-5	8.63 0 0.187 0 8.63 17.45	0 − 1.5 0 + 3,065.2 + 3,063.7

TABLE C (Continued)

VALUES OF $\Sigma\delta L$ AND $K\Sigma\delta L$ (Continued)

Joint	L	δL	$\Sigma\delta L$	Member	K	$K\Sigma\delta L$
9				9-6	7.93	
	6-9-7	− 46.8	− 46.8	9-7	3.31	− 154.9
	7-9-8	− 21.2	− 68.0	9-8	0.187	− 12.7
	8-9-11	+ 318.0	+ 290.0	9-11	3.08	+ 770.0
	11-9-10	+ 166.1	+ 418.1	9-10	11.07	+ 4,606.5
					25.58	+ 5,208.9
10				10-9	11.07	
	9-10-11	− 328.6	− 328.6	10-11	0.374	− 122.9
	10-11-12	− 317.0	− 645.6	10-12	11.07	− 7,146.5
					22.51	− 7,269.4
11				11-13	3.08	
	13-11-12	+ 447.0	+ 447.0	11-12	0.328	+ 146.6
	12-11-10	+ 158.0	+ 605.0	11-10	0.374	+ 226.3
	10-11-9	+ 162.5	+ 767.5	11-9	3.08	+ 2363.8
	9-11-8	− 312.0	+ 455.5	11-8	0	0
					6.86	+ 2,736.7
12				12-10	11.07	
	10-12-11	+ 159.0	+ 159.0	12-11	0.328	+ 52.2
	11-12-13	− 215.9	− 56.9	12-13	0.187	− 10.6
	13-12-15	− 215.9	− 272.8	12-15	0.328	− 89.5
	15-12-14	+ 159.0	− 113.8	12-14	11.07	− 1259.8
					22.98	− 1307.7
13				13-16	8.63	
	16-13-15	+ 458.9	+ 458.9	13-15	3.08	+ 1413.2
	15-13-12	− 231.1	+ 227.8	13-12	0.187	+ 42.6
	12-13-11	− 231.1	− 3.3	13-11	3.08	− 10.2
	11-13-8	+ 458.9	+ 455.6	13-8	8.63	+ 3931.8
					23.61	+ 5367.4

TABLE D
FORMULATION OF EQUATIONS

Joint #1

			Σ Joint	Member
$40.60 T_1$	$+3,568.0$		1	
$12.37 T_3$	$+10,779.0$		3	3-1
$7.93 T_2$			2	2-1

$40.60 T_1 + 7.93 T_2 + 12.37 T_3 = -14,350.0$ Eq(1)

Joint #2

			Σ Joint	Member
$32.46 T_2$		$-11,920.6$	2	
$7.93 T_1$	$+1784.0$		1	1-2
$0.374 T_3$	$+252.5$		3	3-2
$7.93 T_4$			4	4-2

$7.93 T_1 + 32.46 T_2 + 0.374 T_3 + 7.93 T_4 = +9,884.1$ Eq(2)

Joint #3

			Σ Joint	Member
$50.88 T_3$	$+22,388.0$		3	
$12.37 T_5$		-4854.2	5	5-3
$0.328 T_4$	$+52.2$		4	4-3
$0.374 T_2$		-157.3	2	2-3
$12.37 T_1$			1	1-3

$12.37 T_1 + 0.374 T_2 + 50.88 T_3 + 0.328 T_4$
$+ 12.37 T_5 = -17,428.7$ Eq(3)

Joint #4

			Σ Joint	Member
$33.40 T_4$	$+90.8$		4	
$7.93 T_2$		-5803.0	2	2-4
$0.328 T_3$	$+171.5$		3	3-4
$0.187 T_5$		-27.8	5	5-4
$0.328 T_7$	$+52.8$		7	7-4
$7.93 T_6$			6	6-4

$7.93 T_2 + 0.328 T_3 + 33.40 T_4 + 0.187 T_5 + 7.93 T_6$
$+ 0.328 T_7 = +5515.7$ Eq(4)

Joint #5

			Σ Joint	Member
$49.00 T_5$		-9468.8	5	
$8.63 T_8$	$+3065.2$		8	8-5
$3.31 T_7$	$+1277.2$		7	7-5
$0.187 T_4$		-22.3	4	4-5
$12.57 T_3$			3	3-5

$12.37 T_3 + 0.187 T_4 + 49.00 T_5 + 3.31 T_7$
$+ 8.63 T_8 = +5148.7$ Eq(5)

Joint #6

			Σ Joint	Member
$32.46 T_6$		-4567.2	6	
$7.93 T_4$	$+65.0$		4	4-6
$0.374 T_7$	$+3.3$		7	7-6
$7.93 T_9$			9	9-6

$7.93 T_4 + 32.46 T_6 + 0.374 T_7 + 7.93 T_9 = +4,498.9$ Eq(6)

Joint #7

			Σ Joint	Member
$14.64 T_7$	$+2666.6$		7	
$3.31 T_9$		-154.9	9	9-7
$0.374 T_6$		-116.4	6	6-7
$0.328 T_4$		-49.5	4	4-7
$3.31 T_5$	$+147.6$		5	5-7

$0.328 T_4 + 3.31 T_5 + 0.374 T_6 + 14.64 T_7 + 3.31 T_9$
$= -2493.4$ Eq(7)

Joint #8

			Σ Joint	Member
$34.90 T_8$	$+6127.4$		8	
$8.63 T_{13}$	$+3931.8$		13	13-8
$0.187 T_9$		-12.7	9	9-8
$8.63 T_5$			5	5-8

$8.63 T_5 + 34.90 T_8 + 0.187 T_9 + 8.63 T_{13} = -10,046.5$
Eq(8)

Joint #9

			Σ Joint	Member
$51.16 T_9$	$+10,417.8$		9	
$7.95 T_6$		-2167.2	6	6-9
$3.31 T_7$		-1.5	7	7-9
$3.08 T_{11}$	$+2,363.8$		11	11-9
$11.07 T_{10}$			10	10-9

$7.93 T_6 + 3.31 T_7 + 0.187 T_8 + 51.16 T_9 + 11.07 T_{10}$
$+ 3.08 T_{11} = -10,612.9$ Eq(9)

Joint #10

			Σ Joint	Member
$45.02 T_{10}$		$-14,538.8$	10	
$11.07 T_9$	$+4606.5$		9	9-10
$0.374 T_{11}$	$+226.3$		11	11-10
$11.07 T_{12}$			12	12-10

$11.07 T_9 + 45.02 T_{10} + 0.374 T_{11} + 11.07 T_{12}$
$= +9,706.0$ Eq(10)

Joint #11

			Σ Joint	Member
$13.72 T_{11}$	$+5473.4$		11	
$3.08 T_{13}$		-10.2	13	13-11
$0.328 T_{12}$	$+52.2$		12	12-11
$0.374 T_{10}$		-122.9	10	10-11
$3.08 T_9$	$+770.0$		9	9-11

$3.08 T_9 + 0.374 T_{10} + 13.72 T_{11} + 0.328 T_{12}$
$+ 3.08 T_{13} = -6,162.5$ Eq(11)

Joint #13

$T_{13\text{-}12} = 0 \qquad T_{13} + 227.8 = 0$ Eq(13)

Joint #12

$T_{12\text{-}13} = 0 \qquad T_{12} - 56.9 = 0$ Eq(12)

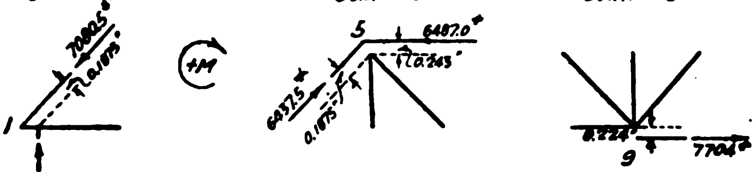
TABLE E1

EQUATIONS (Without effect of Eccentricity of Members)

$40.6\,T_1 + 7.93\,T_2 + 12.37\,T_3 = -14,338.0$ Eq. (1)
$7.93\,T_1 + 32.46\,T_2 + 0.374\,T_3 + 7.93\,T_4 = +9,884.1$ (2)
$12.37\,T_1 + 0.374\,T_2 + 50.88\,T_3 + 0.328\,T_4 + 12.37\,T_5 = -17,427.0$ (3)
$7.93\,T_2 + 0.328\,T_3 + 33.40\,T_4 + 0.187\,T_5 + 7.93\,T_6 + 0.328\,T_7 = +5,515.7$ (4)
$12.37\,T_3 + 0.187\,T_4 + 49.00\,T_5 + 3.31\,T_7 + 8.63\,T_8 = +5,148.7$ (5)
$7.93\,T_4 + 32.46\,T_6 + 0.374\,T_7 + 7.93\,T_9 = +4,498.9$ (6)
$0.328\,T_4 + 3.31\,T_5 + 0.374\,T_6 + 14.64\,T_7 + 3.31\,T_9 = -2,493.4$ (7)
$8.63\,T_5 + 34.90\,T_8 + 0.187\,T_9 + 8.63\,T_{13} = -10,046.5$ (8)
$7.93\,T_6 + 3.31\,T_7 + 0.187\,T_8 + 51.16\,T_9 + 11.07\,T_{10} + 3.08\,T_{11} = -10,612.9$ (9)
$11.07\,T_9 + 45.02\,T_{10} + 0.374\,T_{11} + 11.07\,T_{12} = +9,706.0$ (10)
$3.08\,T_9 + 0.374\,T_{10} + 13.72\,T_{11} + 0.328\,T_{12} + 3.08\,T_{13} = -6,162.5$ (11)
$T_{13} + 227.8 = 0$ Eq (12) $T_{12} - 56.9 = 0$ Eq (13)
From Eqs (12) and (13); $T_{13} = -227.8$ and $T_{12} = +56.9$
These values of T_{12} and T_{13}, substituted in Eqs (8), (10) and (11) give:
$8.63\,T_5 + 34.90\,T_8 + 0.187\,T_9 = -8,080.5$ (8)
$11.07\,T_9 + 45.02\,T_{10} + 0.374\,T_{11} = +9,076.1$ (10)
$3.08\,T_9 + 0.374\,T_{10} + 13.72\,T_{11} = -5,479.6$ (11)

MOMENTS DUE TO ECCENTRICITY OF MEMBERS

Joint #1 Joint #5 Joint #9



Moment $= -7080.5 \times 0.1875$ Moment $= -6487.0 \times 0.243 + 6437.5 \times 0.1875$ Moment $=$
$M_1 = -1327.5$" # $M_5 = -369.2$ $-7704 \times 0.224 = -1725.6$
$-\frac{1}{2}M_1 = +663.8$ For Eq (1) $-\frac{1}{2}M_5 = +184.6$ For Eq (5) $-\frac{1}{2}M_9 = +862.8$ Eq (9)

TABLE E2

EQUATIONS (Effect of Eccentricity of Members included)

$40.6\,T_1 + 7.93\,T_2 + 12.37\,T_3 = -13,674.2$ Eq. (1)
$7.93\,T_1 + 32.46\,T_2 + 0.374\,T_3 + 7.93\,T_4 = +9,884.1$ (2)
$12.37\,T_1 + 0.374\,T_2 + 50.88\,T_3 + 0.328\,T_4 + 12.37\,T_5 = -17,427.0$ (3)
$7.93\,T_2 + 0.328\,T_3 + 33.40\,T_4 + 0.187\,T_5 + 7.93\,T_6 + 0.328\,T_7 = +5,515.7$ (4)
$12.37\,T_3 + 0.187\,T_4 + 49.00\,T_5 + 3.31\,T_7 + 8.63\,T_8 = +5,333.3$ (5)
$7.93\,T_4 + 32.46\,T_6 + 0.374\,T_7 + 7.93\,T_9 = +4,498.9$ (6)
$0.328\,T_4 + 3.31\,T_5 + 0.374\,T_6 + 14.64\,T_7 + 3.31\,T_9 = -2,493.4$ (7)
$8.63\,T_5 + 34.90\,T_8 + 0.187\,T_9 = -8,080.5$ (8)
$7.93\,T_6 + 3.31\,T_7 + 0.187\,T_8 + 51.16\,T_9 + 11.07\,T_{10} + 3.08\,T_{11} = -9,750.1$ (9)
$11.07\,T_9 + 45.02\,T_{10} + 0.374\,T_{11} = +9,076.1$ (10)
$3.08\,T_9 + 0.374\,T_{10} + 13.72\,T_{11} = -5,479.6$ (11)

TABLE F

SOLUTION OF EQUATIONS

No of Eq	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	ABSOLUTE TERM
1	+40.6	+7.93	+12.37									-13,676.2
2	+7.93	+37.46	+0.376	+7.93								+9,806.1
3	+12.37	+0.376	+50.88	+0.528	+12.37							+17,427.0
1'	+1.0	+0.1992	+0.305									-337.0
2'	+1.0	+4.096	+0.0672	+1.0								+1297.0
3'	+1.0	+0.0302	+4.11	+0.0205	+1.0							-1409.0
a	(1' from 2')	+3.90	-0.2570	+1.0								+1580.0
b	(1' from 3')	-0.1690	+3.805	+0.0208	+1.0							-1072.0
4		+7.93	+0.528	+33.60	+0.107	+7.93	+0.528					+6615.7
a'		+1.0	-0.0061	+0.2002								+446.5
b'		-1.0	+22.07	+0.1805	+6.06							-6900.0
4'		+1.0	+0.0046	+4.22	+0.0836	+1.0	+0.0046					+695.0
c	(a' from b')		+22.006	+0.4107	+6.06							-6094.5
d	(a' from 4')		+0.1076	+3.964	+0.0258	+1.0	+0.0046					+288.5
5			+12.37	+0.107	+42.0		+3.31	+2.63				+5333.3
c'			+1.0	+0.0181	+0.2030							-264.1
d'			+1.0	+35.88	+0.2195	+9.31	+0.3059					+2685.0
5'			+1.0	+0.0151	+3.96		+0.2676	+0.098				+431.0
e		(c' from d')		+34.06	-0.0035	+9.31	+0.3005					+2903.1
f		(5' from d')		+36.00	-3.26	+2.31	+0.1180	-0.098				+2754.0
6				+7.93		+32.06	+0.376		+7.93			+6006.0
7				+0.528	+3.31	+0.376	+16.66		+3.31			-2092.6
e'				+1.0	-0.0010	+0.2530	+0.0005					+80.1
f'				+1.0	-0.1016	+0.2520	+0.0080	-0.0093				+81.2
6'				+1.0		+4.096	+0.0672		+1.0			+657.0
7'				+1.0	+1.009	+1.16	+4.06		+12.09			-7000.0
g			(e' from f')		-0.10062	0	-0.00725	-0.0093				-18.9
h			(e' from 7')		+12.09	+0.0072	+10.06		+12.09			-7680.1
i			(f' from 6')		+0.1016	+3.8628	+0.066	+0.0093	+1.0			+505.0
8					+2.63			+3.890	+0.107			-8002.6
g'					-1.0	0	-0.0722	-0.1000				-188.2
h'					+1.0	+0.0000	+4.630		+1.0			-761.0
i'					+1.0	+37.06	+0.033	+0.1005	+9.05			+4970.0
8'					+1.0			+4.005	+0.0017			-937.0
j				(g' from h')		+0.0000	+4.950	-0.1000	+1.0			-969.2
k				(g' from i')		+37.06	+0.361	-0.0023	+9.05			+4781.0
l				(h' from 8')		-0.0000	-4.630	+4.005	-0.9905			-176.0
9						+7.93	+3.31	+0.107	+52.10	+11.07	+3.00	-9750.1
j'						+1.0	+49.60	-2.106	+11.36			-10700.0
k'						+1.0	+0.0005	-0.00006	+0.28			+120.2
l'						-1.0	-92.75	+46.0	-11.10			-2000.0
9'						+1.0	+0.6175	+0.0236	+6.65	+1.395	+0.3805	-1230.0
m					(j' from k')		+49.59	-2.106	+11.10			-10900.2
n					(k' from l')		-90.30	+46.00	-12.86			-1673.0
o					(k' from 9')		+0.4000	+0.0700	+6.10	+1.396	+0.3006	-1360.2
m'							+1.0	-0.0433	+0.2200			-221.0
n'							-1.0	+0.915	-0.2156			-57.3
o'							+1.0	+0.0600	+15.10	+3.02	+0.952	-3525.0
p						(m' from n')		+0.0717	+0.0005			-250.3
q						(o' from n')		+0.973	+16.95	+3.02	+0.957	-3302.3
p'								+1.0	+0.00075			-296.6
q'								+1.0	+15.59	+3.57	+0.980	-3499.0
r							(p' from q')		+15.38	+2.97	+0.980	-3402.5
10									+11.07	+45.02	+0.576	+9670.1
11									+3.00	+0.576	+12.72	-5079.6
r'									+1.0	+0.220	+0.0057	-206.0
10'									+1.0	+4.07	+0.0520	+820.0
11'									+1.0	+0.1226	+4.095	-1779.0
s								(r' from 10')		+2.80	-0.0200	+1083.9
t								(r' from 11')		-3.95	+4.021	-9000.0
s'										+1.0	-0.0070	+262.0
t'										-1.0	+1.19	-857.0
u									(s' from t')		+1.1122	-390.0
u'											+1.0	-352.0
T_n	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	
Results	-309.0	+375.8	-332.2	+33.9	+256.6	+191.2	-179.2	-290.1	-293.8	+264.3	-352.0	
s°										+1.0	+2.7	+267.0
s°°										+1.0		+264.3
r°									+1.0	+10.3	-22.0	-303.9
r°°									+1.0			-293.8
p°								+1.0	-2.4			-296.6
p°°								+1.0				-290.1
m°							+1.0	+12.8	-54.6			-221.0
m°°							+1.0					-179.2
k°						+1.0	-1.72	+0.02	-63.3			+120.2
k°°						+1.0						+191.2
g°					-1.0	0	+12.9	+85.5				-188.2
g°°					+1.0							+256.6
e°				+1.0	-0.3	+48.4	-1.9					+80.1
e°°				+1.0								+33.9
c°			+1.0	+0.6	+67.5							-264.1
c°°			+1.0									-332.2
a°		+1.0	+22.0	+8.7								+446.5
a°°		+1.0										+375.8
1°	+1.0	+73.4	-101.4									-337.0
1°°	+1.0											-309.0

TABLE G
VALUES OF DEFLECTION ANGLES AND FIBRE STRESSES

Joint	Member		$2c/l$	T_n	$\Sigma\delta L$	T_{nm}	$(2T_{nm}+T_{mn})$	Secondary Stress (f_s)	Primary Stress (f_p)	% $\frac{f_s}{f_p}$
1	L_0M_1	1-3	0.0770 T 0.0816 B	-309.0	0	-309.0	- 79.5	- 6.12 + 6.50	-120.7	5.1 —
	L_0L_1	1-2	0.1060		+225.0	- 84.0	+ 207.8	+ 22.0	+120.5	18.2
2	L_1L_0	2-1	0.1060	+375.8	0	+375.8	+ 667.8	+ 70.6	+120.5	58.5
	L_1M_1	2-3	0.0548		-420.5	- 44.7	+ 253.6	+ 13.9	+ 61.62	22.6
	L_1L_2	2-4	0.1060		-731.7	-358.1	- 678.3	- 71.8	+120.5	59.6
3	M_1U_2	3-5	0.0770 T 0.0816 B	-332.2	0	-332.2	- 800.2	-61.8 +65.3	-109.6	56.2 —
	M_1L_2	3-4	0.0329		+523.0	+190.8	+ 574.5	+ 18.9	-67.34	28.1
	M_1L_1	3-2	0.0548		+675.2	+343.0	+ 641.3	+ 35.2	+61.62	56.1
	M_1L_0	3-1	0.0816 B 0.0770 T		+870.7	+538.6	+ 768.0	+62.8 -59.1	-120.7	— 49.0
4	L_2L_1	4-2	0.1060	+ 33.9	0	+ 33.9	- 288.3	-30.6	+120.5	25.4
	L_2M_1	4-3	0.0329		+159.0	+192.9	+ 576.6	+ 18.95	- 67.34	28.2
	L_2U_2	4-5	0.0274		-119.1	- 85.2	- 62.3	- 1.71	+123.2	1.4
	L_2M_3	4-7	0.0329		-150.8	-116.9	- 251.9	- 8.28	-67.34	12.3
	L_2L_3	4-6	0.1060		+ 8.2	+42.1	+ 275.4	+ 29.2	+120.5	24.2
5	U_2U_4	5-8	0.0608 T 0.0692 B	+256.6	0	+256.6	+ 574.3	+ 34.9 - 37.4	-143.5	— 26.0
	U_2M_3	5-7	0.0617		+ 44.8	+301.2	+ 809.1	+ 49.8	+131.5	37.9
	U_2L_2	5-4	0.0274		-148.5	+108.1	+ 131.0	+ 3.59	+123.2	2.9
	U_2M_1	5-3	0.0816 B 0.0770 T		-392.4	-135.8	- 603.8	- 49.2 + 46.4	-109.6	43.2 —
6	L_3L_2	6-4	0.1060	+191.2	0	+191.2	+ 425.5	+45.1	+120.5	37.5
	L_3M_3	6-7	0.0548		-311.2	-120.0	- 410.3	- 22.6	+ 61.62	36.7
	L_3L_4	6-9	0.1060		-273.3	- 82.1	- 408.0	- 43.3	+120.5	35.9
7	M_3L_4	7-9	0.0617	-179.2	0	-179.2	- 649.0	-40.1	+109.5	36.6
	M_3L_3	7-8	0.0548		+ 8.9	-170.3	- 460.8	-25.3	+ 61.62	41.0
	M_3L_2	7-4	0.0329		+161.1	- 18.1	- 153.1	- 5.04	- 67.34	7.5
	M_3U_2	7-5	0.0617		+385.9	+208.7	+ 714.6	+44.1	+131.5	33.5

TABLE G (Continued)

DEFLECTION ANGLES AND FIBRE STRESSES (Continued)

Joint	Member		$2c/l$	T_n	$\Sigma\delta l$	T_{nm}	$(2T_{nm}+T_{mn})$	Secondary Stress (f_s)	Primary Stress (f_p)	% $\frac{f_s}{f_p}$
8	U_4U_6	8-13	0.0608 T 0.0652 B	−294.1	0	−294.1	− 360.4	− 21.9 + 23.5	−143.5	15.2 —
	U_4L_4	8-9	0.0274		− 7.8	−301.9	− 915.6	− 25.1	0	—
	U_4U_2	8-5	0.0652 B 0.0608 T		+ 355.2	+ 61.1	+ 378.8	+ 24.7 − 23.0	−143.5	— 16.0
9	L_4L_3	9-6	0.1060	−243.8	0	−243.8	− 569.7	−60.3	+120.5	50.0
	L_4M_3	9-7	0.0617		−46.8	−290.6	− 760.4	−46.9	+109.5	42.8
	L_4U_4	9-8	0.0274		− 63.0	−311.8	− 925.6	−25.3	0	—
	L_4M_5	9-11	0.0617		+250.0	+ 6.2	+ 427.9	+26.4	−72.94	36.2
	L_4L_5	9-10	0.1089 T 0.1030 B		+416.1	+172.3	+ 608.9	+66.2 −62.6	+127.6	52.0 —
10	L_5L_4	10-9	0.1030 B 0.1089 T	+264.5	0	+264.3	+ 700.9	+72.2 −76.2	+127.6	56.6 —
	L_5M_5	10-11	0.0548		−328.6	− 64.3	+ 124.4	+ 6.85	+61.62	11.1
	L_5L_6	10-12	0.1089 T 0.1030 B		−645.6	− 381.3	− 705.7	−76.9 +72.7	+127.6	— 57.0
11	M_5U_6	11-13	0.0617	−352.0	0	−352.0	− 935.1	− 57.7	−48.62	118.8
	M_5L_6	11-12	0.0529		+447.0	+ 95.0	+ 405.9	+13.4	−67.34	19.9
	M_5L_5	11-10	0.0548		+605.0	+ 253.0	+ 441.7	+24.2	+61.62	39.3
	M_5L_4	11-9	0.0617		+767.5	+415.5	+ 837.2	+51.7	−72.94	71.0
12	L_6L_5	12-10	0.1030 B 0.1089 T	+ 56.9	0	+ 56.9	− 267.5	−27.8 +29.1	+127.6	— 22.8
	L_6M_5	12-11	0.0529		+159.0	+215.9	+ 526.8	+17.4	−67.34	25.9
	L_6U_6	12-13	0.0274		− 56.9	0	0	0	+123.2	—
13	U_6L_6	13-12	0.0274	−227.8	+227.8	0	0	0	+123.2	—
	U_6M_5	13-11	0.0617		− 3.3	−231.1	− 814.0	−50.2	−48.62	103.0
	U_6U_4	13-8	0.0652 B 0.0608 T		+455.6	+227.8	+161.5	+10.51 − 9.82	−143.5	6.8

+ Denotes Tension − Denotes Compression

T Denotes Top Fibre B Denotes Bottom Fibre

II—BENDING MOMENTS IN MEMBERS OF A TRANSVERSE FRAME DUE TO DEFLECTION OF FLOOR BEAMS.

Where floor beams are rigidly connected to vertical posts, as in the usual modern design, the deflection of the floor beams produces certain deflections of the posts in a transverse plane with corresponding bending stresses. This problem can readily be approximately analyzed as follows:

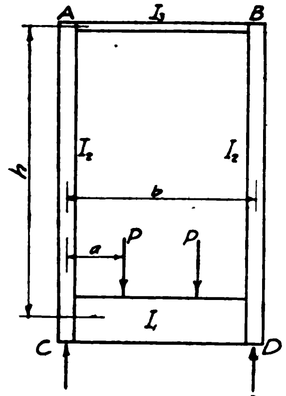


FIG. 1.

Fig. 1 shows a tranverse frame consisting of beams, posts and overhead transverse bracing. We may consider two cases: first, if the transverse bracing is so slender, or the connection such that the post may be considered as hinged at A and B; and second, if the bracing and connection are sufficiently rigid that the post may be considered as fixed at A and B, then, taking into account the deflection of the beam and posts, and placing equal to zero, the deflection of A relative to B, the following formulas for the bending moments at C and D are derived:*

First case (hinged at A and B) $M = P\dfrac{3a\,(b\text{-}a)\,I_2}{2hI_1 + 3bI_2}$

Second case (fixed at A and B) $M = P\dfrac{2a\,(b\text{-}a)\,I_2}{hI_1 + 2bI_2}$

It can be shown that under the above assumptions, and for the usual spacing of track stringers in single-track bridges, the ratio of fiber stress in the post to the fiber stress in the center of the beam is approximately as follows:

$$\frac{f_p}{f_b} = .7\frac{c_2}{c_1} \text{ to } 1.0\frac{c_2}{c_1}$$

in which f_p = fiber stress in post, f_b = fiber stress at beam center, c_1 = depth of beam and c_2 = width of post. Thus, the ratio of post stress to

*For a derivation of these formulas see p. 502, Part II, Johnson's "Modern Framed Structures."

maximum beam stress is nearly equal to the ratio of widths of members. For example, if the depth of beam is 48 in. and width of post 16 in., the ratio of the respective widths is .25 and, therefore, the bending stress in the post will be approximately from 20 to 25 per cent. of the bending stress in the center of the beam, assuming the usual spacing of stringers.

Results of observation bear out these theoretical conclusions. Bending stresses in posts have been observed as high as 40 per cent. of the floor beam stress, and invariably the observations have shown quite large values. In the case of the compression verticals, or posts, the maximum bending stresses would not occur simultaneously with the maximum post stress; however, an increase of 20 to 25 per cent. in the maximum primary stress may be expected from this cause. The narrower the posts and the deeper the beams the less this secondary stress. In the case of the tension verticals, such as hip verticals, the maximum bending stress would occur simultaneously with the maximum primary stress, thus increasing very greatly the maximum fiber stress in the member.

Another possible cause of lateral bending in verticals is the presence of transverse bracing of the type shown in Plate VI, in which transverse struts are not used at every panel point. The bending stresses due to this cause would not be a maximum at the section where the moment from other causes is a maximum.

III—STRESSES IN A HORIZONTAL PLANE DUE TO LONGITUDINAL DEFORMATION OF CHORDS, ESPECIALLY STRESSES IN FLOOR BEAMS AND CONNECTIONS.

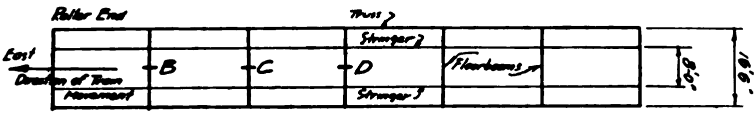
Results of Observation.—In the usual arrangement of floor members in a through bridge the elongation of chords causes a considerable horizontal bending of floor beams. This bending effect is cumulative from the center towards the ends of a span, and in long-span structures the resulting stresses are very large. This effect is well recognized and the use of expansion joints in stringer connections in long-span trusses is now a common practice.

In the experiments of 1911 a study was made of actual stresses due to this cause. The most complete sets of observations were made on the small trusses C and D of Plate VII. Extensometers were placed on each side of the lower flange and complete records of stresses were obtained for several movements of the test train. Both the horizontal bending stress and the stress due to vertical load were thus obtained. The results are given in detail below.

It is to be noted that the maximum horizontal bending stress does not always occur simultaneously with the maximum vertical bending. The maximum horizontal bending occurs, in general, when the structure is fully loaded or nearly so. Hence, with the train headed towards the

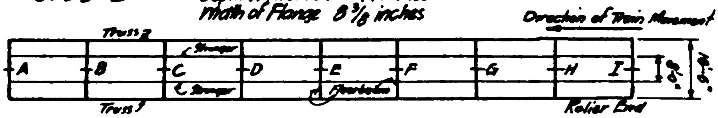
left, the locomotive will rest upon the beams in the left half of the span, while the right half will be loaded with the train. It follows that in the left half of the span the two maxima will occur nearly simultaneously, while in the right half the maximum vertical moment will occur first and be followed by maximum horizontal moment.

TRUSS "C"   Span 104 ft.
Depth of Floorbeam 45 inches
Width of Flange 12 3/8 inches



Floorbeam	Maximum Horizontal Bending Stress lb. per sq in.	Approximate Maximum Vertical Bending Stress lb. per sq. in.	Percent Horizontal to Vertical
B	4400	5200	85
C	3300	"	65
D	1100 (Right)	"	21

TRUSS "D"   Span 105 ft.
Depth of Floorbeam 41 inches
Width of Flange 8 3/8 inches



Floorbeam	Maximum Horizontal Bending Stress lb. per sq. in.	Approximate Maximum Vertical Bending Stress lb. per sq. in.	Percent Horizontal to Vertical
A	2900	2100	138
B	2950	3100	95
C	1870	"	60
D	1140	"	37
E	470 (Right)	"	15
F	1100 (Left)	"	35
G	1770	"	57
H	2400	"	77
I	2700	2100	129

Several other observations of a less complete character were made on floor beams near the ends of trusses, with resulting bending stresses of from 2,000 to as high as 8,000 lbs. per sq. in.

Approximate Method of Calculation.—If it is assumed that the axis of the stringers does not elongate; that the stringer connections are

unyielding, and that the ends of the beams remain vertically over the joint centers, then it follows that the horizontal deflections of the beams must correspond to the elongation of the chords. If it is assumed that the center beam remains straight, the deflection of the adjacent beams must be equal to the elongation of the one panel of the chord; the deflection of the next beam will be equal to the elongation of the two panels, etc. In Fig. 2, C D represents the first beam from the center.

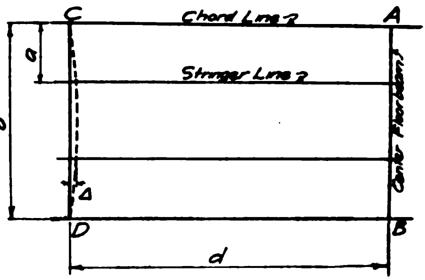


FIG. 2.

The deflection Δ is taken equal to the elongation of chord $CA = \dfrac{d \times s}{E}$, where $s =$ unit stress in the chords and $E =$ modulus of elasticity. Although the joints at C and D are more or less rigid, it may be assumed that as regards horizontal bending, the beam is free to turn at the ends. In this case the deflection of the beam in terms of maximum fiber stress is

$$\Delta = \frac{fa}{6Ec}(3b\text{-}4a)$$

in which $f =$ fiber stress, $c =$ half of flange width. Placing this deflection equal to $\dfrac{d \times s}{E}$ and solving for f we derive

$$f = \frac{6cd}{a\,(3b\text{-}4a)}s.$$

Assuming, for example, $d = 300$ in., $c = 6$ in., $b = 192$ in., and $a = b \div 4$, we find that $f = .58s$. For the second beam $f = 1.16s$, etc.

In these calculations it has been assumed that the stringers are not elongated at all and that the connection to the beams permits of no deformation whatever. Practically, the riveted joint is not entirely rigid, as the connection angles, the rivets, and the web of the beam all contribute to the deformation. The stringers, also, receive some longitudinal stress, although the amount per square inch of section is small. On the whole, the deflections and stresses in the beams are not as great as

deduced from the above calculations, but they are often large and of much importance. As the calculations show, they increase with the width of the beam and with the number of panels, and are greater as the distance a becomes smaller.

Applying the above method of calculation to the two sets of observations previously given, we have for truss C the following values: $d = 208$ in., $b = 16.5$ ft., $a = 4.25$ ft., $c = 6.2$ in. The observed average value of chord stress s was approximately 5,200 lbs. per sq. in. From the formula we derive from these values, for the first beam, $f = .39s =$ 2,000 lbs. per sq. in.

For truss D we have $d = 157.5$ in., $c = 4.2$ in., $s = 4{,}700$ lbs. per sq. in. The values of b and a are the same in truss C. Applying the formula, we have $f = .20s = 940$ lbs. per sq. in. per panel.

Comparing the calculated values with the observed values, we have the following results:

TRUSS C.

Panel Point—	Observed Values, lbs. per sq. in.	Calculated Values, lbs. per sq. in.
Center beam	1,100	0
Beam C	3,300	2,000
Beam D	4,400	4,000

TRUSS D.

		Observed Values, lbs. per sq. in.	Calculated Values, lbs. per sq. in.
Center beam		470	0
First beam	D	1,140	940
	F	1,100	
Second beam	C	1,870	1,880
	G	1,770	
Third beam	B	2,950	2,820
	H	2,400	
Fourth beam	A	2,900	3,760
	I	2,700	

The correspondence between observed and calculated values is much closer than could ordinarily be expected and closer than similar estimates in some other cases. It is probably true that in longer spans, where the beams are deeper, the actual stresses in the beams towards the end of the span are not as great as this approximate theory would call for. However, the values actually observed, as well as the theoretical analysis, shows that these stresses are very large in such cases. In one long span the horizontal bending in the end floor beam was so great as to be readily noted by the eye, and the floor beam web had become permanently dished by the pull of the stringers. Conditions are especially unfavorable in double-track structures where the distance between outside stringer and end of beam is relatively small.

Stresses in Lower Laterals and Lateral Connections.—Besides the stresses in beams and connections the extension of the chords gives rise to considerable stress in the lateral members and their connections. With fairly rigid joints the unit stress in the laterals may easily reach one-third to one-half the unit stress in the chords themselves. In the end panels, where the chord section is small and the laterals relatively large, a considerable proportion of the chord stress will be carried by the laterals. This consideration shows the importance of good lateral connections, especially near the end of the span. Several observations on end posts and end sections of lower chords showed very high secondary stresses in these members, due, undoubtedly, to eccentric connections of lower laterals.

IV—VARIATION OF AXIAL STRESS IN DIFFERENT ELEMENTS OF A MEMBER.

In addition to the secondary stresses in a vertical plane due to rigid joints, there will exist more or less bending in a direction at right-angles to the vertical plane. Some of this bending has already been discussed under III. A considerable amount of bending or inequality of stress exists, however, in other members, such as the chords and diagonals, which will be briefly considered. In the case of eye-bar members this lateral bending will be shown in the inequality of stress in the various bars; in the case of riveted members it will be shown as a lateral bending similar to the bending in a vertical plane. It is impossible to apply theoretical analysis to any extent in this case, but results of observations will be of considerable value as indicating probable limits of stress due to this cause.

As already stated elsewhere, lateral bending has been found to be large in some cases in the end post and lower chord. The following percentages of secondary stress in a lateral direction were observed:

Truss A—End post, 75 per cent.; top chord at portal, 24 per cent.

Truss B—End post, 37 per cent.; lower chord, 10 per cent.

Trusses A and B are skew bridges.

Truss C—End post, 12 per cent.; chord, 3 per cent.

Truss D—End post, 19 per cent.; chord, 10 per cent.

Excepting in such cases as above noted, the observed lateral bending stresses in riveted members were generally small. For example, in truss A in four cases the average was 3 per cent., with maximum of 5 per cent.; in truss C the average was 3 per cent. and maximum 6 per cent. In truss D the maximum in the bottom chords was 9 per cent. and in the top chord 13 per cent.

A number of observations were made with reference to the equality of stress in eye-bars. In truss B the stresses in the four bars of the bottom chord showed a variation in one panel of 31 per cent. above the average, and in another panel, of 19 per cent. above the average. In

this same truss the variation in the two bars of the diagonal members in various panels ranged from 1 per cent. to 19 per cent., averaging 12 per cent. Various observations made on other structures showed a variation in diagonal stress ordinarily from 10 to 20 per cent. above and below the average. Sometimes the maximum stress occurred in the inside diagonal and sometimes in the outside diagonal.

V—STRESSES DUE TO VIBRATION OF INDIVIDUAL MEMBERS.

In the case of long eye-bar diagonals it was frequently observed, during the progress of the work, that under certain conditions such members would vibrate very considerably in a vertical plane. In one case where these bars were very long the observed vibration would cause a stress of about 3,000 lbs. per sq. in. This was a rather extreme example, but in many other cases vibrations were observed which would cause stress of 1,000 to 1,500 lbs. per sq. in. Comparatively little vibration was noted in chord bars, and, in general, it may be said that, excepting in very light and short spans, eye-bar members, for lower chords, are very satisfactory in this respect.

VI—METHODS OF CALCULATION.

Since the methods of analysis of secondary stresses are not commonly taught in engineering schools and little used in practice, the Committee deemed it desirable to present a brief outline of the theory and a fully worked-out example of its application.

Appendix D

REQUIREMENTS FOR THE PROTECTION OF TRAFFIC AT MOVABLE BRIDGES.

The protective appliances at drawbridges consist in devices for insuring that the bridge is in proper position, and the track in condition for the passage of trains over draw, or for reduction to a minimum of the damage in case of trains not stopping when track is not in condition for passage of same over draw; also the usual devices for protection against damage in case of derailment.

The protective devices may be classified under the headings:

(A) Interlocking power and bridge devices.
(B) Bridge surfacing, aligning and fastening devices.
(C) Rail end connections.
(D) Signaling and interlocking.
(E) Guard rails.

(A) INTERLOCKING POWER AND BRIDGE DEVICES.—Interlocking the drawbridge devices so that their movements must follow in a predetermined order to protect the drawbridge machinery.

(B) BRIDGE SURFACING, ALIGNING AND FASTENING DEVICES.—Drawbridges should be equipped with proper mechanism to surface and align them accurately and fasten them securely in position. This condition can be secured by the use of efficient end lifts in case of swing bridges, and by proper end locks in case of lift bridges.

(C) RAIL END CONNECTIONS.—Rail ends should be cut square and connected by sliding sleeve or joint bars, or by easer rails to carry the wheels over the opening between the end of bridge and approach rails; the outside of the head of the main rail to be planed off to a width of 2 inches for the length required by easer rail or joint bar.

(D) SIGNALING AND INTERLOCKING.—If trains are to proceed over drawbridges which are in service, without first stopping, interlocking should be installed which will provide that the draw span, tracks and switches within the limits of the plant are locked in the proper position. This will require:

(1) Locking drawbridge devices.

(2) Locking providing for the proper order of operation of signaling devices, such as signals, switches and derails.

This interlocking will require the following order of operation:

BEFORE OPENING A DRAWBRIDGE.	BEFORE OPERATING TRAINS OVER DRAWBRIDGE.
1. Display stop signals.	1. Lock bridge and rail devices.
2. Unlock rail and bridge devices.	2. Display clear signals.

Since there are various types and designs of drawbridges and various drawbridge devices for each of the types, and also various designs and types of signaling devices, as well as various locations from which they all may be interlocked and operated, a typical example only of the detail order of operations is given; viz., a swing bridge with all its devices operated from one location on the draw span, having home and distant signals, derails, etc.

TO OPEN DRAWBRIDGE.

1. Display stop signals.
2. Unlock derails.
3. Open derails.
4. Uncouple interlocking connections.
5. Unlock rail end connections.
6. Unlock bridge surfacing, aligning and fastening devices.
7. Withdraw rail end connections.
8. Withdraw bridge surfacing, aligning and fastening devices.
9. Open bridge.

TO PASS TRAINS OVER DRAWBRIDGE.

1. Close bridge.
2. Insert bridge surfacing, aligning and fastening devices.
3. Insert rail end connections.
4. Lock bridge surfacing, aligning and fastening devices.
5. Lock rail end connections.
6. Couple interlocking connections.
7. Close derails.
8. Lock derails.
9. Display clear signals.

DERAILS.—The above example of order of operation includes derailing switches, but their use is not recommended in all cases. Each situation must be given special study with respect to (a) the use of derails, smash boards or similiar devices; (b) their location with respect to draw span, and (c) the use and length of guard rails.

(E) GUARD RAILS.—There should be two lines of guard rails of rail section, placed between the running rails, which should extend from the approaches continuously over the bridge, except for the necessary breaks at the ends of the draw span. The top of the guard rails should preferably be level with the top of the main rail and not in any case more than one inch below it. There should be a clear space of ten inches between the head of the guard rail and the gage side of the main rail. The guard rails should be full spliced and bolted and be fastened at the same intervals and by the same methods as the main rail. Obstructions to derailed wheels which are guided by the guard rails should be reduced to a minimum. The guard rails shall be brought together at a point not less than 75 feet beyond the ends of the bridge, the ends of the rails to be beveled or otherwise effectively formed so that dragging objects will be deflected. When traffic is in one direction, the guard rails should be extended as described on the approaching end of the bridge only.

Electric and Time Locking.—Electric and time locking are regarded as adjuncts.

Railway Signal Association's Standards.—The interlocking should be constructed in accordance with Railway Signal Association's standards, and the various bridge devices should be so designed that standard interlocking apparatus may be used.

Insulation of Rails and Attachments.—The rails and attachments should be separated from the metallic structure so track circuits may be successfully operated the entire length of the bridge.

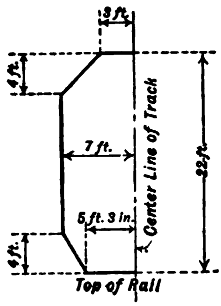
Appendix E.

BRIDGE CLEARANCE DIAGRAM.

At the request of the Committee, the following circular letter was sent out by the Secretary to different railway officers to obtain information to aid in the study of the bridge clearance diagram. As no recommendation is to be made by Committee XV this year, it has been decided to present the replies received as information.

It may be noted that there is quite a general feeling that the whole clearance diagram should be considered rather than a modification for third rail.

It should also be noted that some of the Public Service Commissions are taking action and in some cases fixing dimensions which will seriously increase the cost for portal and vibration bracing without increasing safety.



"Last year a modification of the bridge clearance diagram (see page 404 of the 1911 Manual) to make room for the third rail construction for electric traction was referred to the Committee on Iron and Steel Structures for investigation and report. After considerable discussion it was decided to be undesirable to make the change suggested without a careful consideration of the entire diagram. The subject was reassigned to the Committee and it has been referred to a Sub-Committee to obtain the information necessary for a proper study of the subject.

"To aid in this work you are earnestly requested to answer the inquiries given on attached sheet as promptly as possible, directing your reply to Mr. C. L. Crandall, Professor of Railway Engineering, Cornell University, Ithaca, N. Y.

"(1) Do you favor a modification of the bridge clearance diagram for third rail for electric operation, as suggested, by widening to 5 ft. 6 in. down to top of rail?

"(2) Do you favor a diagram wide enough to include third rail by widening the base without other changes in the diagram as shown in the Manual, p. 404?

"(3) Minimum diagram which you would recommend for new structures?

"(4) Minimum diagram used on your road: (a) Existing structures. (b) New structures. (c) Yards or where there is switching service?

"(5) Would you distinguish between main and branch lines?

"(6) What is your general practice with street bridges with solid floors where girders between tracks are necessary?

"(7) Do you believe roads using the present minimum (see above diagram) would suffer loss due to the recommendation of a larger diagram by the Association in view of the fact that several states have already passed laws enlarging the clearance diagram and that many roads use greater clearances?"

Atlantic Coast Line (J. E. Willoughby, Assistant Chief Engineer):

(1) Yes, for through truss bridges; no, for through girders.

(2) No.

(3) Standard A. R. E. A. modified for through truss to 7 ft. top of rail.

(4) Standard A. R. E. A. for all new structures and changes.

(5) No.

(6) Do not build any.

(7) Yes.

Ann Arbor Railroad (L. J. Allen and A. W. Towsley, Vice-President and General Manager):

(1) No.

(2) No.

(3) Present diagram except 7 ft. 6 in. from center of track.

(4) (a) 7 ft. (b) 7 ft. 6 in. (c) 13 ft. c. to c. of track.

(5) No.

(6) ——

(7) Not if made to apply to new work.

Atchison, Topeka & Santa Fe (C. F. W. Felt, Chief Engineer):

(1) Yes. Better to have line start 5 ft. 6 in. from center of track at top of rail and run straight to a point 7 ft. from center of track at height of 4 ft. above top of rail.

(2) Favor retention of present diagram with change recommended in No. 1; think alternate diagrams providing widths of 7½ ft. and 8 ft., respectively, from center line should be prepared where clearance is necessary or advisable.

(3) See No. 2.

(4) See blueprint. (The blueprint gives the clearance for Chicago 13 ft. wide above 4 ft. 3 in. from top of rail and 16 ft. high; those for other portions of the line apparently 14 ft. and 15 ft. wide and 22 ft. high; the California R. R. Commission 15 ft. and 16 ft., and the clearance for buildings 16 ft.)

(5) No, except would re-erect old spans on branch lines to wear them out, and accept a less clearance on branch lines than on main line.

(6) See diagram.

(7) Think unqualified adoption of larger diagram would cause trouble.

Baltimore & Ohio (Earl Stimson, Engineer Maintenance of Way):

(1) Yes. The 5 ft. 4½ in. at base of rail in B. & O. diagram practically same as 5 ft. 6 in. top of rail.

(2) Yes.

(3) See diagram (14 ft. for bridges with 10 ft. 9 in. at base of rail).

(4) Standard clearances are required on all structures.

(5) No.

(6) No exceptions from standard diagram.

(7) Believe recommendation of larger diagram by Association would tend toward state and government legislation requiring greater clearance, which would cause some roads loss.

Boston & Albany (F. B. Freeman, Chief Engineer):

(1) Yes.

(2) ——

(3) See print (15 ft. with 11 ft. at top of rail).

(4) ——

(5) No.

(6) Secure at least 7 ft. 6 in. in clear if possible.

(7) No.

Chicago, Rock Island & Pacific (C. A. Morse, Chief Engineer):

(1) Yes.

(2) No.

(3) Eight feet center of track to truss.

(4) (a) 7 ft. center of track to truss. (b) 8 ft. center of track to truss. (c) 8 ft.

(5) No.

(6) ——

(7) No.

Carolina, Clinchfield & Ohio (Ward Crosby, Chief Engineer):

(1) Yes.

(2) ——

(3) ——

(4) See diagram (15 ft. with 11 ft. at base of rail).

(5) No.

(6) We have none. Widen tracks apart to get full clearance if possible.

(7) No.

Chicago, Burlington & Quincy (G. H. Bremner, Engineer Illinois District):

(1) Yes.

(2) Yes.

(3) See attached print (14 ft. for through girders, 15 ft. 6 in. for trusses).

(4) See attached print (no difference shown).

(5) No.

(6) Clear all equipment.

(7) Yes. Any increase in clearance will result in greater cost of structures.

Chicago Great Western (L. C. Fritch, Chief Engineer):

(1) Yes.

(2) No.

(3) C. G. W. R. R. standard (16 ft. with 11 ft. at top of rail).

(4) —
(5) No.
(6) Have no cases of this nature.
(7) Yes.

Chicago & Northwestern (W. H. Finley, Assistant Chief Engineer):

Blueprint standard shows 16 ft., 3 ft. above top of rail, 13 ft. 1 ft. above, 11 ft. 6 in. above, and 10 ft. 4 in. at top, changing by steps, not by slope lines.

Chicago, Milwaukee & St. Paul (E. O. Reeder, Assistant Chief Engineer:)

As neither the Tacoma Eastern nor the lines of the C. M. & St. P. Ry. are now or are likely to be in the near future operated in the manner mentioned, I have not given the matter sufficient study to permit me to properly answer the inquiries.

Chicago, St. Paul, Minneapolis & Omaha (C. W. Johnson, Chief Engineer):

No electrification of this road is at present contemplated, and we therefore have no standard covering third rail.

Cleveland, Cincinnati, Chicago & St. Louis (O. E. Selby, Engineer Bridges and Structures):

(1) Yes.

(2) No.

(3) Print attached (15 ft. wide, 4 ft. from base with 11 ft. at base and 22 ft. high from top of rail).

(4) (a) 7 ft. lateral, 19 ft. overhead. (b) Print attached. (c) Lateral 8 ft. from center line of track down to top of rail.

(5) No.

(6) Girders extend above rail only as permitted by attached diagram when applied to adjacent tracks.

(7) No. Minimum legal clearances are usually less than desirable working standards.

Colorado & Southeastern (F. W. Whiteside):

(1) Yes.

(2) Yes.

(3) Same as diagram (of circular) except base which would be 5 ft. 6 in. or more.

(4) Twenty-two feet vertical, 12 ft. wide at base, 14 ft. wide at point 4 ft. above top of rail and balance of way up.

(5) No.

(6) We have none.

(7) Yes.

Delaware & Hudson (Geo. H. Burgess, Chief Engineer):

(1) Yes.

(2) Yes.

(3) See diagram base 5 ft. 6 in., central portion 15 ft. to within 5 ft. of top; top 7 ft. Other dimensions as on diagram of circular.

(4) (a) As above except width 14 ft. and length 21 ft. (b) As above. (c) As above except width 16 ft.

(5) No.

(6) Keep depth of girder and width of cover plates such as not to come within clearance lines.

(7) Depends largely upon number and age of structures having minimum diagram. If of recent date it would require considerable expense to change structures for clearances which would otherwise be good for several years' service.

Denver & Rio Grande (A. O. Ridgway, Assistant Chief Engineer):

(1) Do not think 5 ft. 6 in. at top of rail sufficient.

(2) No.

(3) See diagram (shows width of 15 ft. 6 in. with 12 ft. at top of rail; height 23 ft. from top of rail).

(4) (a) Not available. (b) See diagram. (c) We are endeavoring to conform to attached diagram.

(5) No.

(6) Conformity to attached diagram.

(7) No.

Detroit, Toledo & Ironton (G. R. Endert, Chief Engineer):

(1) Yes.

(2) Yes.

(3) Item No. 1.

(4) (a) Rectangle 13 ft. wide 16 ft. high. (b) No record existing clearance yards. New ones to be in excess of main line.

(5) No.

(6) Has none.

(7) Loss would be of more or less extent.

Duluth & Iron Range (W. A. Clark, Chief Engineer):

The last legislature of this state passed a drastic clearance law which may be modified by the Railroad and Warehouse Commission. As I do not yet know what action they will take, I feel that it would be useless for me to express any opinion at the present time regarding a standard clearance diagram.

Duluth, South Shore & Atlantic (E. R. Lewis, Assistant to General Manager):

I desire to express myself as not favoring a modification of the bridge clearance diagram by widening it to accommodate third rail for electric operation. While I believe such procedure may be desirable on a very few railroad divisions, I do not believe it will be generally necessary for some years to come.

I am of the opinion that roads using the present minimum clearance would suffer loss from such a recommendation by the Association.

El Paso & Southwestern System (J. L. Campbell, Engineer Maintenance of Way):

(1) Yes.

(2) Yes.

(3) ——.

(4) (a and b) 6 ft. at top of rail.

(5) No.

(6) Have none.

(7) ——.

Elgin, Joliet & Eastern (A. Montzheimer, Chief Engineer):

(1) Yes.

(2) Yes.

(3) Eight feet at level of car floor and 6 ft. 6 in. at top of rail.

(4) (a) 7 ft. from center of track. In some cases the gussets are brought down so close to rail that doors on steel dump cars have injured them. (b) 8 ft. from center of track. (c) In most cases 8 ft. clearance.

(5) No.

(6) It is our practice to keep the floor up as high as possible between girders so as to give better clearance between tracks.

(7) No. There is no doubt but what wider clearances will be required in future.

Erie (R. C. Falconer, Superintendent of Construction):

(1) Yes. Our present practice is to provide 5 ft. 6 in. at base of rail.

(2) Present practice is to provide side clearance 7 ft. 6 in. between 7 ft. and 19½ ft. above base of rail where possible.

(3) See diagram (as above with height of 24 ft. 6 in. above base of rail).

(4) (a) As above for many years, although some bridges in track with less. (b and c) As above.

(5) No.

(6) Maintain our standard clearance, keeping girders outside of clearance line.

(7) Suggest modification for future construction only and would thus impose no hardships on roads using smaller diagrams.

Ferrocarriles Nacionales de Mexico (J. M. Reid, Chief Engineer):

(1) Yes.

(2) Would prefer 7 ft. 6 in. instead of 7 ft.

(3) Seven feet 6 in. clearance from center line, 5 ft. 6 in. at top of rail, other dimensions same as shown.

(4) (a) Same as diagram. (b) 7 ft. 6 in. 5 ft. 6 in. Standard Nat. Rys. of Mexico. (c) 6 ft. 6 in. instead of 7 ft.

(5) No.

(6) None in use.

(7) No, because present clearance is sufficient to keep the bridges in use until necessary to replace them by new ones.

Florida East Coast (E. B. Carter, Superintendent Maintenance of Way):

(1) Have had no actual experience upon which to base an opinion.

(2) No actual experience.

(3) That shown on diagram on this sheet.

(4) (a, b and c) 22 ft. overhead, 9 ft. 6 in. from center line sideways.

(5) No.

(6) Have no bridges of this type.

(7) Believe such roads would suffer loss.

Georgia (W. M. Robinson, Roadmaster):

(1) Yes.

(2) Yes.

(3) Same as in Manual.

(4) (a) As marked on diagram (10 ft. width at top of rail, 12 ft. central portion).

(5) No.

(6) None on our line.

(7) No.

Gulf & Ship Island (W. H. Gardner, Jr., Chief Engineer):

(1) Do not have any electric operation.

(2) ——.

(3) Present one. (See Manual.)

(4) (a) Bridges. (b) None.

(5) No.

(6) Have none.

(7) Expect some would.

Grand Trunk (H. R. Safford, Chief Engineer):

(1) See diagram (13 ft. top of rail, 16 ft. from 3 ft. to 17 ft. above rail, 7 ft. at top, height 22 ft. from top of rail).

(2) Would favor above diagram.

(3) Would favor above diagram.

(4) Would favor above diagram.

(5) No; would prefer uniform standard.

(6) We arrange, if possible, to keep top of girder not more than 3 ft. 6 in. above base of rail to have body of car clear girder. Where this is not possible with a double track bridge, we omit the center girder and provide two outer girders only.

7. Believe the larger diagram will eventually be enforced.

Great Northern (R. Budd, Chief Engineer):

(1) No third rail experience.

(2) No third rail experience.

(3) Plan attached, as used in Canada (10 ft. base of rail, 11 ft. 4 in. top of guard, 4 in. up, 16 ft. between 4 ft. 4 in. and 16 ft. 7 in., 12 ft. 10 in. at 19 ft. 11 in., 8 ft. at top, 22 ft. 6 in. from base).

(4) U. S. diagram (for bridges in the United States, 10 ft. at base, 11 ft. 4 in. top of guard 4 in. up, 15 ft. between 4 ft. 4 in. and 16 ft. 6 in., 11 ft. 10 in. at 19 ft. 10 in., 7 ft. at top, 22 ft. 5 in. from base).

(5) No.

(6) Girders do not encroach on diagram, tracks being spaced far enough apart to admit of this.

(7) Yes.

Gulf, Colorado & Santa Fe (F. Merritt, Chief Engineer):

It seems to me that this has special reference to electrically-operated railways, of which there are none under my jurisdiction, and have therefore no suggestions to make regarding this subject.

(4) Height 18 ft. 4 in., width 14 ft. (b) Height 23 ft., width 14 ft.

Hocking Valley (Wm. Michel, Chief Engineer):

(1) Yes.

(2) No.

(3) Width 11 ft. at base, 15 ft. from 4 ft. to 18 ft. up, 6 ft. at top, 22 ft. up.

(4) (a) Same as in Manual. (b and c) Same as 3.

(5) No, not for new work.

(6) Keep center girders below 4 ft. line.

(7) Not for new work.

Hudson & Manhattan (J. V. Davies, Chief Engineer):

This company would hardly deem it advisable to make any recommendations as to modifications of existing bridge clearance diagram, as the whole character of our structure, equipment and operation (entirely electrical) would not necessitate in any way, in my mind, any change from the existing diagram.

From personal experience I do not think there is any necessity for changing this diagram by widening to 5 ft. 6 in. down to top of rail, which would make it more difficult to design half through girder bridges and other such structures. For electric train service could advantageously reduce height from existing 22 ft. to something less in view of the large number of cases where electric service is installed.

Houston & Texas Central (I. A. Cottingham, Assistant General Manager):

(1) Yes.

(2) Yes.

(3) See diagram (11 ft. at top of rail, 15 ft. between 4 ft. and 18 ft. 7 in. above rail center with height of 23 ft. 7 in. from top of rail).

(4) (a) Width 14 ft., height 20 ft. from top of rail. (b and c) See diagram.

(5) No.

(6) Use deck girders.

(7) No.

Interborough Rapid Transit (Geo. H. Pegram, Chief Engineer):

The subject of modifying the bridge clearance diagram does not relate directly to the elevated railways and subways operated by the I. R. T. Co. In the case of the elevated railways, the equipment of cars and tracks for electric traction was designed largely to suit the structure as built. In the case of the subway, many factors govern the amount of clearance that can be provided, and it is therefore not feasible to adopt a standard clearance that is adapted to trunk lines.

Blueprint enclosed shows 20¾ in. from center of running rail to outside of third rail and 24¾ in. from same point to the guard rail.

International & Great Northern (O. H. Crittenden, Chief Engineer):

(1) No.

(2) No.

(3) Present standard.

(4) (a) Present standard. (b) Present standard. (c) Have none.

(5) No.

(6) We have no street bridges.

(7) Yes.

Kansas City, Mexico & Orient (R. P. Parker, Chief Engineer):

(1) I do.

(2) No.

(3) Five ft. 6 in. down to top of rail, 8 ft. above.

(4) (a) 16 ft. inside to inside. (b) No change . (c) Same.

(5) No.

(6) Same clearance as with trussed bridge.

(7) I do not, as I think the most of the states shortly will recommend larger diagrams.

Lehigh Valley (E. B. Ashby, Chief Engineer):

(1) Yes, as indicated for No. 2.

(2) Yes, only the lower bevel to be changed.

(3) Eleven ft. at top of rails, otherwise same as diagram.

(4) (a)—(b) Same as 3. (c) Same as 3. The height of 20 ft. from top of rail shown, with overhead clearance in special cases made less than shown as conditions may require, but not less than 16 ft.

(5) No.

(6) We endeavor to provide the same clearance at all bridges. In special cases the side clearance for intermediate girders may have to be reduced to maintain spacing of tracks.

(7) The enlargement of the diagram will increase the cost of bridges. The changing from 10 ft. 6 in. to 11 ft. 0 in. will reduce the length of span for which intermediate girders can be placed unless the tracks are spread.

Long Island (J. R. Savage, Chief Engineer):

(1) No. Believe such change unnecessary.

(2) Do not believe any change from one shown on margin is required. (See Manual).

(3) As per diagram on margin.

(4) See copies attached. (The blueprint attached is a composite showing the outside dimensions of cars, with minimum structure clearance of 10 ft. at base of rail, 11 ft. 7 in. from 4 ft. up to 6 ft. 10 in., 12 ft. 6 in. from 6 ft. 4 in. to about 12 ft., narrowing irregularly to a flat top at 15 ft. 2 in. The minimum diagram differs from this by widening to 13 ft. from 6 ft. 10 in. to 13 ft. up and narrowing uniformly to 4 ft. at top 17 ft. from base).

(5) No.

(6) If question refers to overhead crossing of R. R., increase spacing of track centers to 15 ft., preferably 16 ft.

(7) Undoubtedly they would.

Louisville & Nashville (W. H. Courtenay, Chief Engineer):

(1) No.

(2) No.

(3) As shown on margin (11 ft. at base, 15 ft. between 4 ft. and 15 ft. up and 8 ft. at top with height of 22 ft.).

(4)

(5) No.

(6) We have none.

(7) Probably yes.

Mississippi River & Bonne Terre (C. H. Fake, Chief Engineer):

We have no third rail electric traction and therefore prefer not to express an opinion.

Missouri & North Arkansas (E. M. Wise, General Manager for Receivers):

As we have had no experience with third rail construction, we are not in position to make any recommendations or report thereon.

Missouri Pacific (C. E. Smith, Br. Engineer):

(1) Yes.

(2) No.

(3) Fifteen ft. by 22 ft.

(4) (a) Eleven ft. by 16 ft. (b) Fifteen ft. by 22 ft. (c) Eight ft. side. Not less than 18 ft. Effort always made to get 22 ft. overhead.

(5) No.

(6) Have done none of this work.

(7) Not if a reasonable increase were made, say 15 ft. by 22 ft. (This is accompanied by a blueprint showing suggested clearances permitted by the Illinois R. R. & Warehouse Commission September 16, 1912. These show rectangle 13 ft., 17 ft., 17 ft. wide respectively and 15 ft., 18 ft., 22 ft. high from top of rail for the three classes of roads, and allow no bracing except for the upper corners of the 17 ft. by 22 ft., and these are limited to 3 ft. each way from the corner.

Mobile & Ohio (B. A. Wood, Chief Engineer M. of W. and S.):

(1) Yes.

(2) No.

(3) Fourteen ft. 6 in.

(4) (a and b) 14 ft. (c) Tracks 12 ft. center to center in yard.

(5) No.

(6) Have none.

(7) No.

Newburgh & South Shore (A. H. Stewart, Engineer Maintenance of Way):

(1) Yes.

(2) Yes.

(3) Diagram adopted in Manual with above changes in base.

(4) (a and b) Am. Ry. Eng. Assoc.

(5) No.

(6) Constructed ten years ago with clearance of four ft. at rail top.

(7) No.

Lake Erie & Western (W. G. Atwood, Chief Engineer):

(1) No.

(2) No.

(3) Are now using and recommend clearance of 7 ft. 6 in. each side of center line.

(4) (a) Fourteen ft. (b) Fifteen ft. (c) Fifteen ft.

(5) I would not so distinguish.

(6) We sometimes permit slight encroachments on the diagram at points below 4 ft. above the rail.

(7) Do not believe that these roads would suffer, or that legislation could well be retroactive and affect existing structures. The Indiana law is 7 ft. 6 in. from center line, but had not heard of any attempt to cause reconstruction of existing bridges; in fact, the law provides for these cases by giving the Commission authority to approve their use. I believe that the Association should recommend a clearance diagram that it believes is proper, regardless of whether it is in general use or not.

Nashville, Chattanooga & St. Louis (Hunter McDonald, Chief Engineer):

(1) No.

(2) Yes, if impossible to obtain room for third rail otherwise.

(3) Diagram shown above. (See Manual).

(4) (a) See Drawing 519-36E herewith (blueprint shows tunnel section 11 ft. at top of rail, 11 ft. 6 in. 6 ft. from base and 15 ft. 10 in. center height. It shows a bridge clearance of 12 ft., with height of 16 ft. 5¼ in. from top of rail). (b) Diagram shown above. (c) Diagram shown above.

(5) No.

(6) Raise floor so that diagram shown above is cleared.

(7) Yes.

New York, New Haven & Hartford (E. Gagel, Chief Engineer; W. J. Backes, Engineer Maintenance of Way):

(1) The bridge clearance should be modified for third rail electric operation by widening to 5 ft. 6 in. at top of rail.

(2) Widening diagram shown in Manual, at the base to include the third rail does not seem sufficient, as the maximum width of the present diagram is 7 ft., and 7 ft. 6 in. is much better for through bridges.

(3) Not smaller than shown in N. Y., N. H. & H. Specifications, 1912. (Sketch shows 11 ft. for 1 ft. from top of rail; widens to 12 ft. 4 in. at 3 ft. 9 in. and is 15 ft. from 3 ft. 9 in. to 17 ft. 6 in. and 8 ft. at top 21 ft. from rail.

(4) (a) Diagram attached. (Diagram shows 10 ft. 6 in. at top of rail, 14 ft. 6 in. from 7 ft. 3 in. to 16 ft. up and 7 ft. at top 21 in. from rail). (b) (c) Sketch attached.

(5) We do not.

(6) We use N. Y., N. H. & H. Specification 1912, and where necessary spread tracks to obtain required depth of girders.

(7) No.

New York, Ontario & Western:

(1) Yes.

(2) Yes.

(3) See Sketch 1912 Specifications. (Eleven ft. top of rail, 15 ft. between 4 ft. and 15 ft. and 8 ft. at top 21 ft. up).

(4) (a) About same as diagram 404 Manual, except clear head room above top of rail is 21 ft. (b) and (c) 1912 Specifications.

(5) No.

(6) Same clearance as Specifications 1912.

(7) No.

New Orleans Great Northern (R. H. Howard, General Manager):

(1) Yes.

(2) No. Diagram should be changed otherwise.

(3) See print (11 ft. top of rail, 14 ft. from 4 ft. to 18 ft. 6 in. and 7 ft. at top 23 ft. 6 in. above rail).

(4) (a), (b), (c) See print.

(5) No.

(6) None constructed.

(7) Yes.

Norfolk & Western (J. E. Crawford, Acting Chief Engineer):

(1) Yes.

(2) Yes.

(3)

(4) (a) See Specifications January 1, 1911. (Eleven ft. base of rail, 15 ft. between 4 ft. and 17 ft, 6 ft. at top 23 ft. from base).

(5) No.

(6) Spread the tracks or use deck girders.

(7) Yes.

Northern Electric (A. D. Schindler, Vice-President and General Manager):

Clearances on railroads in this state (California) are governed by an order of the State Railroad Commission, a copy of which is enclosed. All our new construction is in accordance therewith. (The regulations fix the minimum clearance at 22 ft. from top of rail where standard freight cars are to be used, at 19 ft. for street railroads not hauling standard freight cars and 14 ft. if in a street. The side clearance is fixed at 7½ ft. for bridges and tunnels).

Northern Pacific (W. L. Darling, Chief Engineer):

Has no electric operation and is therefore without experience.

Oregon Short Line (Carl Stradley, Assistant General Manager):

(1) Would not recommend simply on account of installation of third rail, as it is possible that in near future the third rail may become obsolete. There are other reasons which would appear to me sufficient to make standard clearance at top of rail 5 ft. 6 in.

(2) Depends upon the amount of money involved in making changes. I believe the larger clearance would be much safer and more satisfactory.

(3) Same as for new structures. See diagram:

(4) (a) See drawing 17964 (height, base of rail, 20 ft. 1 in. branch line, 20 ft. 10 in. main line, width 14 ft.).

(4) (b) See drawing 17964 (height base of rail, 24 ft., width 11 ft. at base of rail 15 ft. between 4 ft. and 19 ft. and 6 ft. at top). (c) For general conditions, diagrams would be similar to drawing 17964. However, for special cases special design would be made.

(5) No.

(6) Drawing 17964 except for special cases.

(7) Yes, if this leads to laws forcing the railroads to increase the present clearance, when the railroads do not believe it necessary, especially upon roads not strong financially.

Otsego & Herkimer (R. P. Waller, Engineer Maintenance of Way):

My experience in the use of bridge clearance diagrams in actual practice has been so limited that I do not feel qualified to pass opinions on most of these questions. The Otsego & Herkimer is a trolley system throughout, so that questions with regard to third rail practice do not come up.

Pennsylvania Lines West of Pittsburg (W. C. Cushing, Chief Engineer Maintenance of Way):

(1) Yes.

(2) Do not seriously object to small modifications.

(3) Chairman Public Service Commission of Ohio called representatives of the railroads of that state together June 19 and appointed a committee of seven railroads to prepare rules and regulations. Unknown what the Commission will do, as the personnel has been changed.

(The report places minimum overhead clearance at 21 ft. from rail, which may by consent be reduced to 17 ft. for overhead crossings in cities and towns. The lateral clearance is placed at 7 ft. between 4 ft. and 15 ft. from top of rail 5 ft. at top of rail except for mail cranes and passenger stations platforms, and 3 ft. at top of vertical clearance).

(4) (a) Diagram (shows 17 ft. from top of rail for grade separation work in cities and 21 ft. for regular work and width of 14 ft.). (b) Seventeen ft., 22 ft. 6 in. and 15 ft., respectively.

(5) No.

(6) Endeavor to eliminate girders entirely by use of columns, and where it is impossible endeavor to keep the girders as low as possible above top of rail.

(7) I do not think so, provided any laws or rules issued by states are not made retroactive, but apply only to future work.

Pennsylvania—P. B. & W., N. C., W. J. & S. (L. R. Zollinger, Engineer Maintenance of Way):

(1) Yes.

(2) See diagram B (11 ft. top of rail, 14 ft. from 4 ft. 6 in. to 17 ft., 6 ft. at top, with height of 22 ft.).

(3) See diagram B.

(4) See diagram A (rectangle 12 ft. plus gage of track by 16 ft. from top of rail except intertrack fence and station platform high and low. The height to be 22 ft. where practicable. (b) See diagram B. (c) See diagram C (rectangle 9 ft. 2 in. plus gage wide by 16 ft. high from top of rail, except for freight transfer platforms 4 ft. high 3 ft. 9 in. from gage lines.

(5) No.

(6) Wherever possible structures are built in accordance with diagram B.

(7) Yes.

Philadelphia & Reading (F. S. Stevens, Engineer Maintenance of Way):

(1) Yes.

(2) Yes. A width of 11 ft. 0 in. at top of rails.

(3) The above diagram with width at base 11 ft. 0 in.

(4) ——.

(5) No.

(6) When girders project above top of rail they are spaced 14 ft. ctrs. for flanges 14 in. wide.

(7) ——.

Pittsburg, Shawmut & Northern (H. S. Wilgus, Engineer Maintenance of Way):

(1) Have no third rail and cannot answer.

(2) Do.

(3) The 7 ft. should be at least 8 ft.; on this road 7 ft. leaves but 1 ft. 9 in. clearance between cab and structure. Have killed one man and seriously injured another on a bridge with 7 ft. clearance.

(4) Cooper's specifications.

(5) No. Not on this road, where heavy power is used indiscriminately.

(6) No such bridges here.

(7) Larger diagram should be used. See answer to No. 3.

Queen & Crescent (C. Dougherty, Chief Engineer):

(1) No recommendation.

(2) No recommendation.

(3) Eight ft. side clearances between 4 ft. and 18 ft. above top of rail; 22 ft, 0 in. vertical clearance; top width of 9 ft. and bottom width of 11 ft. 0 in.

(4) (a) Six ft. 9 in. each side center line of track. (b) Same as 3. (c) Seven ft. side clearance.

(5) No.

(6) Tracks are spread to give at least 7 ft. 3 in. side clearance.

(7) ——.

Richmond, Fredericksburg & Potomac (S. B. Rice, Engineer Maintenance of Way):

(1) Yes.

(2) Yes.

(3) Base should be 5 ft. 6 in.

(4) (a) As above. (b) As above. (c) They are not affected.

(5) No.

(6) We spread tracks to give clearance.

(7) Would only recommend the use of a larger diagram for new structures.

St. Louis & San Francisco (F. G. Jonah, Chief Engineer):

(1) Yes.

(2) Yes.

(3) Sixteen ft. horizontal, 23 ft. vertical.

(4) Enclosed herewith (9 ft. 10 in. bottom, 14 ft. between 3 ft. 9 in. and 15 ft. 4 in. and 6 ft. 4 in. at top 19 ft. 2 in. up).

(5) No.

(6) Maintain standard clearance—spread tracks if necessary.

(7) Yes, probably would temporarily. Might have to remove some bridges before their life was up.

San Pedro, Los Angeles & Salt Lake (R. K. Brown, Engineer Maintenance of Way):

(1) This company has had no experience in the development of clearance for third rail traction, as none of the line has been electrified.

Southern (B. Herman, Chief Engineer Maintenance of Way and Structures):

(1) See specifications (11 ft. top of rail, 14 ft. 6 in. from 3 ft. 6 in. to 18 ft., 6 ft. 6 in. at top 22 ft. up).

(2) Have no third rail.

(3) ——.

(4) ——.

(5) No.

(6) Wherever possible through girders in the yards are designed to come outside this clearance diagram.

(7) ——.

Spokane, Portland & Seattle (A. M. Tupper, Chief Engineer):

(1) Yes.

(2) No.

(3) See sketch attached (11 in. 6 ft. base of rail, 14 ft. 6 in from 4 ft. to 18 ft. 6 in. and 7 ft. at top 22 ft. 6 in. up).

(4) (a) 19 ft. vertical — 7 ft. 0 in. long. (b) and (c) See sketch.

(5) No.

(6) Have none.

(7) Yes.

Sunset-Central Lines (W. B. Scott, President):

(1) Yes.

(2) Yes.

(3) See Diagram A (11 ft. top of rail, 15 ft. from 4 ft. to 18 ft. 7 in. and 6 ft. at top 23 ft. 7 in. up).

(4) (a) Diagram B (14 ft. 2 in. from top of rail to 17 ft. 8 in. and 6 ft. 2 in. at top 21 ft. 8 in. up).

(5) No.

(6) Use deck girders.

(7) No.

Susquehanna & New York S. T. Hays, Jr., Chief Engineer):

(1) Electric operation has never been considered.

(2) Electric operation has never been considered.

(3) Electric operation has never been considered.

(4) See print. (a) (Nine ft. 4 in. base of rail, 14 ft. from 4 ft. 6 in. to 16 ft. 6 in. and 6 ft. at top 21 ft. 6 in. up.) (b) Diagram (11 ft. at base of rail, 15 ft. from 4 ft. 6 in. to 16 ft. 6 in. and 6 ft. at top 21 ft. 6 in. up).

(5) Yes, in certain cases.

(6) We require a special design for each particular case and allow top flanges of longitudinal girders inside clearance lines from 8 to 12 in. when between 3 ft. 6 in. and 6 ft. 6 in. above base rail.

(7) For existing structures would necessitate expensive renewals and work a hardship on our company.

Union Pacific (Assistant General Manager):

We have no third rails on the Union Pacific system, and therefore presume that the clearances which we are using will be of no benefit in answer to the inquiries referred to.

Western Pacific (T. J. Wyche, Chief Engineer):

(1) Have no third rail track.

(2) Have no third rail track.

(3) Fifteen ft. 6 in. clear width, 23 ft. 0 in. clear height.

(4) (a) Fourteen ft. 0 in. clear width, 20 ft. 6 in. clear height. (b) Fifteen ft. 6 in. clear width for middle 15 ft., 7 ft. 6 in. at top, 12 ft. 0 in. at top of rail, 23 ft. 0 in. clear height. (c) Have no through bridges in yards.

(5) Not in purchasing new bridges for branch lines.

(6) Have none.

(7) Yes, as future state laws would probably be governed by A. R. E. A. Standard.

Wheeling & Lake Erie (W. L. Rohbock, Chief Engineer):

(1) Yes.

(2) Yes.

(3) See sketch (5 ft. 6 in. from center at base. No other change from Manual).

(4) Use A. R. E. A. diagram on all lines.

(5) No.

(6) Make diagram the same for both tracks.

(7) We should not be compelled to alter old bridges in order to conform to new diagram, as this in many cases would be extremely expensive.

REPORT OF COMMITTEE VIII—ON MASONRY.

G. H. TINKER, *Chairman;*
R. ARMOUR,
J. C. BEYE,
C. W. BOYNTON,
W. A. CLARK,
T. L. CONDRON,
J. K. CONNER,
G. W. HEGEL,
L. J. HOTCHKISS,

F. L. THOMPSON, *Vice-Chairman;*
RICHARD L. HUMPHREY,
J. H. PRIOR,
F. E. SCHALL,
G. H. SCRIBNER, JR.,
A. N. TALBOT,
FRANK TAYLOR,
JOB TUTHILL,
J. J. YATES,

Committee.

To the Members of the American Railway Engineering Association:

Meetings of the Masonry Committee during the past year have been held as follows: Sub-Committee "A" on September 11, 1913, at Buffalo, N. Y. Whole Committee on November 8 and December 20, 1913, at Chicago. The work of the Committee has been conducted largely by correspondence.

The following Sub-Committees have dealt with the subjects assigned for investigation:

Sub-Committee "A," "Waterproofing of Masonry and Bridge Floors," F. E. Schall, Chairman; F. L. Thompson, R. Armour, J. K. Conner, L. J. Hotchkiss, Richard L. Humphrey, J. H. Prior, J. J. Yates.

Sub-Committee "B," "Effect on Concrete Structures of Rusting of the Reinforcing Material," C. W. Boynton, Chairman; J. C. Beye, W. A. Clark, G. W. Hegel, G. H. Scribner, Jr.

Sub-Committee "C," "Principles of Design of Plain and Reinforced Concrete Retaining Walls, Abutments and Trestles," T. L. Condron, Chairman; C. W. Boynton, L. J. Hotchkiss, J. H. Prior, A. N. Talbot, Frank Taylor, Job Tuthill.

Joint Committee on Concrete and Reinforced Concrete, C. W. Boynton, G. H. Scribner, Jr., F. L. Thompson, Members; L. J. Hotchkiss, J. H. Prior, F. E. Schall and Job Tuthill, Alternates.

Joint Committee on Standard Specifications for Cement, C. W. Boynton, F. E. Schall.

REVISION OF THE MANUAL.

No revision of the Manual is recommended at this time.

WATERPROOFING OF MASONRY.

The subject of Waterproofing of Masonry has been under investigation by the Committee for the past five years. During this time a large amount of information has been collected and analyzed. Progress re-

ports have been made at the eleventh, twelfth and thirteenth annual conventions, and a final report is presented at this time. A bibliography of the subject was published in Vol. 12 of the Proceedings.

DISINTEGRATION OF CONCRETE.

The subject of "Effect on Concrete Structures of Rusting of the Reinforcing Material" has been considered under the more general subject of "Disintegration of Concrete," a report upon which is herewith presented.

JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

The Joint Committee on Concrete and Reinforced Concrete held no meeting during 1913. Its report, adopted by the American Society of Civil Engineers in January, by the American Railway Engineering Association in March and by the American Society for Testing Materials in June, was given publicity and criticism invited. The Committee will endeavor, in 1914, to round out its report to represent the best American practice.

COMMITTEE C-1—STANDARD SPECIFICATIONS FOR CEMENT, AMERICAN SOCIETY FOR TESTING MATERIALS.

In October, 1912, a sub-committee of Committee C-1 (American Society for Testing Materials) on Standard Specifications for Cement, was appointed to co-operate with a sub-committee of the Departmental Committee of the Government in an effort to harmonize the differences existing between the specifications adopted by Committee C-1 and the specifications written by the Departmental Committee, and by executive order put into effect as a standard specification for cement for all departments of the Government.

As the Methods of Tests on which Committee C-1 based its specifications were prepared by a committee of the American Society of Civil Engineers, which has been dismissed, that Society was asked to appoint a special committee to co-operate with the sub-committee of the Departmental Committee and the sub-committee of Committee C-1. These committees are organized as a Joint Conference on Uniform Methods of Tests and Standard Specifications for Cement.

By unanimous vote, the Chairman of Committee C-1 was authorized to appoint this sub-committee of three, and though neither of our representatives was appointed, they approved of the action taken.

A number of meetings of the Joint Conference have been held, and several tests and investigations conducted. Considerable progress has been made in reconciling differences, and it is expected that the Conference will be in position to make a report during the current year.

The only meeting which Committee C-1 held during 1913 occurred at the Engineers' Club, Philadelphia, December 2. This meeting was called to consider reorganization of the Committee and to discuss the autoclave test with Mr. G. J. Ray, Chief Engineer, and Mr. H. J. Force, Chief Chemist of the Lackawanna Railroad. The time was entirely consumed in discussing the autoclave, and the meeting was adjourned to reconvene in the same place January 7, 1914.

NEXT YEAR'S WORK.

It is recommended that the subject of "Principles of Design of Plain and Reinforced Retaining Walls, Abutments and Trestles" be continued and a further effort be made to obtain some data upon the pressure of earth upon retaining walls.

It is also recommended that the Specifications for Plain and Reinforced Concrete Masonry be revised.

CONCLUSIONS.

(1) It is recommended that the conclusions under "Waterproofing of Masonry and Bridge Floors" be adopted and published in the Manual. (See page 536.)

(2) It is recommended that the conclusions under "Disintegration of Concrete" be adopted and published in the Manual. (See page 568.)

Respectfully submitted,

COMMITTEE ON MASONRY.

Appendix A.

WATERPROOFING MASONRY AND BRIDGE FLOORS.

In compliance with the instructions of the Board of Direction, the Committee has further investigated the subject of "Waterproofing Masonry and Bridge Floors" and submits the following report:

Masonry construction should usually be impervious to water in order that it may be protected from possible disintegration. The presence of water within masonry structures not designed to retain water is objectionable.

The effect of percolating water upon the masonry cannot be estimated as to the number of years the life of the structure may be shortened. Records are lacking from which a comparison of the life of an impermeable masonry structure might be made with one through which water percolates freely. Were such information to be had, no doubt more attention would be devoted to watertight construction.

Probably the fact that water usually is objectionable in structures and the degree in which watertightness affects the requirements of a particular structure, in most cases determine the amount of effort to be spent to obtain watertightness.

The following classification includes the ordinary requirements calling for watertight construction and special methods of waterproofing.

Structures should be waterproof when it is necessary:

(1) To prevent dampness in walls above grade, and in walls and floors below grade.

(2) To prevent flooding of basements and pits which are at all times or occasionally below the ground water level.

(3) To prevent percolation or leakage of water through the masonry and the formation of unsightly deposits on exposed surfaces.

(4) To prevent the dripping of water through a bridge floor over a street, and in the cases of solid floors of steel or reinforced concrete bridges, to protect the steel from corrosion.

(5) To prevent the entrance of water into tunnels, either above or below ground water level, or subaqueous tunnels.

(6) To prevent leakage from reservoirs.

(7) To prevent the penetration of water into the masonry.

The outline given below includes the ordinary methods of waterproofing:

(I) COATINGS.

(1) Linseed oil paints and varnishes.

(2) Bituminous:
Asphalt.
Coal Tar.

(3) Liquid hydrocarbons.

(4) Miscellaneous compounds.

(5) Cement mortar.

(II) MEMBRANES.

Felts and burlaps in combination with various cementing compounds.

(III) INTEGRALS.

(1) Inert fillers.

(2) Active fillers.

(IV) WATERTIGHT CONCRETE CONSTRUCTION.

GENERAL DESCRIPTION OF THE VARIOUS METHODS OF WATERPROOFING AND THEIR APPLICATION.

Walls above grade are waterproofed by coating with paints, varnishes, or waterproofing washes, or by plastering with cement mortar. The coating or plaster may be applied either on the inside or outside of the wall.

The walls of basements and pits are waterproofed, either by the application of coatings, membranes, integral or watertight concrete construction. Membranes are usually protected with concrete, brick or bituminous binder.

Where basement or pit walls and floors are below the ground water level, they must be so designed as to resist the existing hydrostatic head in order to prevent cracks and leakage. Such walls may be waterproofed by the integral method or by watertight concrete construction. When exterior waterproofing is employed, the membrane method is generally used properly protected.

Stone, brick or concrete arches, retaining walls, abutments, subway walls and culverts are waterproofed by any of the methods mentioned in the preceding paragraph. For important structures, the membrane method is most generally used.

When surface coatings, integral waterproofing or watertight concrete construction is used, particular attention must be paid to reinforce the work against cracks due to expansion, contraction or settlement. The expansion joints must be waterproofed by sheet copper or lead built into the adjoining sections.

The solid floors of steel and reinforced concrete bridges probably present the most difficult problems of waterproofing. In steel troughs or I-beam floors a concrete filling may be used to bring the deck up level with, or above the top of the steel in the floor. The floors of this class of structures are usually waterproofed by the membrane method.

Tunnels in which the ground water level is below the invert may be waterproofed by any of the aforementioned methods.

Subaqueous tunnels present a different and distinct problem of waterproofing: usually reinforced concrete, or plain concrete, with iron or steel lining is used. The structures are designed to resist the hydrostatic head.

The walls and floors of reservoirs may be waterproofed by any of the four methods before mentioned.

(I) COATINGS.

(1) LINSEED OIL PAINTS AND VARNISHES.

Linseed oil paints and all coatings containing linseed oil are reactive to atmospheric conditions and to alkaline water. Applied as a damp-proofing to the surface of a concrete wall which may be permeable to moisture, the paint is likely to be of short life, unless the surface is specially prepared. (See Appendix, pp. 537, 538.)

To secure the best results, the wall must be dry and clean before application. The paint is applied with a brush in the ordinary manner. The coating power of paint is approximately 200 sq. ft. of wall per gallon of paint, but varies with the thickness of the paint and the nature of the surface.

The prices of the paints sold for damp-proofing masonry and concrete surfaces vary from about $1.00 to $3.00 per gallon for the material.

(2) BITUMINOUS COATINGS.

This class includes asphalt, petroleum residuum, coal tar and coal tar pitch. As used for waterproofing purposes, they are solid at ordinary temperatures and are, therefore, often applied while hot. As they are soluble in benzine and coal tar naphtha, they are frequently mixed with these solvents and applied in a liquid form. Two coats cost about one cent for material and one-quarter cent for labor per square foot.

ASPHALT.

Waterproofing by the application of liquified asphalt, as a paint applied with a brush or mop, has been used on practically all kinds of engineering structures as a surface coating.

Bituminous coatings applied cold by dissolving in naphtha, instead of hot, do not set instantly, therefore are much easier to apply. The work can be done by an ordinary laborer, care rather than skill being required in its handling. All walls that are to be waterproofed must first be allowed to dry.

If the waterproofing is made by dissolving the bitumens in a volatile solvent with a dryer so that it may be applied cold like a paint, it is difficult, if not impossible, to prepare a paint that will dry to the right consistency and then stop. The usual result is that the drying and hardening continues until it reaches a point where its waterproofing qualities are destroyed.*

Hot asphalt will not adhere to cold, damp concrete. Several different methods of heating the surface of the concrete have been used. Gasoline has been poured over the surface and burned; hot sand has been spread over the surface and swept back as the waterproofing proceeds. It is claimed, however, that heating the surface draws up moisture and prevents the asphalt from adhering. It is necessary that the concrete be thoroughly dry before the asphalt mixture is laid upon it, as the steam

adhesion. Good results have been obtained by first painting the surface to be treated with a priming coat of asphalt cut with naphtha or benzine and then applying the hot asphalt over this coat.

In applying hot asphalt directly to steel, difficulty is found in getting the asphalt to adhere to the steel, and no dependence can be placed upon adhesion to vertical surfaces.

The asphalt should be heated in a suitable kettle to a temperature not exceeding that allowed in the specifications for any particular structure depending upon the material used. If this temperature is exceeded, it may result in pitching the asphalt. Before the pitching point is reached, the vapor from the kettle is of a bluish tinge, which changes to a yellowish tinge after the danger point is exceeded. The asphalt has been cooked sufficiently when a piece of wood can be put in and withdrawn without the asphalt clinging to it. Care should always be taken not to prolong the heat to such an extent as to pitch the asphalt. Should it become necessary to hold the heated asphalt for any length of time, the fire should be drawn or banked and a quantity of fresh asphalt should be introduced into the kettle to reduce the temperature. Excessive heat converts the petroline or cementitious constituents of the asphalt into asphaltene, which is devoid of cementing properties and by so much reduces the cementing quality—the vital element—of the asphalt. The fire should not be allowed to come into direct contact with the melting kettle or tank. Asphalt coatings cost about sixty-five cents per gallon for material and three-tenths cent for labor per square foot, a gallon covering about 100 sq. ft. per coat. (See Appendix, p. 538, Asphalt.)

ASPHALT MASTIC.

Various results have been obtained by the use of asphalt mastic, and it is probable that much is dependent upon the quality of the mastic. The requirements of a sand for asphalt mastic are much the same as those for cement mortar. It is common practice to mix a certain amount of limestone screenings with the sand, with the intention of securing an aggregate with the least percentage of voids. The strength and compactness of the mastic will depend considerably upon the percentage of voids, and the proportion of asphalt used in the mastic should be sufficient to fill the voids and completely coat each particle of sand and screenings. Too much asphalt will produce a mastic that is soft and easily indented, does not offer a good protection against the ballast on a bridge floor and flows more readily than a well-proportioned mixture.

The asphalt and sand are separately heated to from 325 to 350 degrees. The proper proportions are measured out simultaneously, poured into a mixing vessel and thoroughly mixed. The operation of mixing the asphalt mastic requires care in heating the ingredients to secure uniform temperature, not to overheat the asphalt, to proportion the mixture accurately, and to mix the materials thoroughly. The mixture is dumped in place and spread evenly over the surface with wooden floats, shovels or rakes. After being compressed with tampers, the surface is finished with hot smoothing irons.

Asphalt mastics are usually applied in layers not exceeding ⅝ in. in thickness, usually two coats are applied, the coats to break joints not less than one foot. The cost of asphaltic mastic 1¼ in. thick is about $30.00 for material per net ton, a ton covering about 375 sq. ft.; the cost of labor is about two to five cents per square foot, depending upon location and conditions. (See Appendix, Asphalt.)

COAL TAR AND COAL TAR PITCH.

Tar produced by the distillation of bituminous coal is used in waterproofing, either applied cold as a paint by dissolving in naphtha or benzine or applied hot. It is also mixed with sand, gravel or screenings to form a mastic. See American Railway Engineering Association Bulletin 131, January, 1911, Report of Committee VI—Buildings, for information on coal tar.

It is generally found to be difficult to obtain coal tar of good quality. Good coal tar compares favorably with asphalt as a waterproofing material.

The present price of coal tar pitch, used for waterproofing, is about $17.50 per net ton. (See Appendix, p. 543, Use of Tar.)

COAL TAR PAINT.

Annapolis mixture is a coal tar paint composed of one part kerosene oil, four parts Portland cement and sixteen parts refined coal tar.

The mixture is put on with a paint brush in the same way as ordinary paint is applied. The compound not only covers the surface, but sinks into and bonds with it, so that two or three coats are sometimes required. It has been found to adhere to moist or even wet concrete.

The cost for three coats is about one-half cent for material and about one-half cent for labor per square foot. (See Appendix, p. 543.)

(3) LIQUID HYDROCARBONS—PARAFFIN AND PETROLEUM.

Waterproofing by the application of a coating of melted paraffin has been used on masonry in much the same manner as hot asphalt. Paraffin is also applied cold as a paint made by dissolving the paraffin with naphtha.

Petroleum oil is sometimes applied to the surface of masonry as waterproofing.

The efficiency of these materials depends upon their absorption into the surface of the masonry. Applied to clean, dry surfaces of porous masonry, they are fairly efficient as damp-proofing.

(4) MISCELLANEOUS COMPOUNDS—SOAP WASHES.

Solutions of soap applied as a wash for waterproofing or dampproofing masonry surfaces are not recommended, as no permanent waterproofing effect can be depended upon.

SOAP AND ALUM WASHES.

Waterproofing by alternate washes of soap and alum is one of the oldest methods of treating masonry surfaces, and has given fair results when properly used on surfaces sufficiently dense and impermeable to

afford support for the void-filling material. Inferior materials and workmanship cannot be atoned for by the use of alum and soap washes. The alum and soap combine and form an insoluble non-absorptive compound in the pores of the masonry surface.

The cost of applying two coats each of soap and alum washes is about one-half cent per square foot of surface. (See Appendix, p. 543.)

MISCELLANEOUS SURFACE COATINGS. (See Appendix, p. 543.)

(5) CEMENT MORTAR.

The method of waterproofing masonry structures by the application of a plaster coat has proved efficient when the plaster has been properly applied.

The surface to be waterproofed must be clean to insure bond between plaster and masonry. Old surfaces may be cleaned by chipping off a thin layer from the face or by the use of a sand blast or steam jet. The surface must then be kept wet until it has absorbed water to its full capacity.

A wash of neat cement mortar should then be applied with a brush. This wash should be mixed to the consistency of cream and should never be used after it is 45 minutes old. The plaster should be applied over the cement wash before the latter has commenced to dry.

The sand to be used in the mortar should receive careful attention. It should be well graded from fine to coarse, the maximum size of particles being that passing a No. 8 sieve. Portland cement and sand should be mixed in the proportion of 1:1½. The mortar should be applied in layers about ⅜ of an inch thick if more than one coat is used. Each coat should be applied before the preceding one has attained its final set. Good workmanship is essential and the use of a wooden float is necessary in order to obtain a dense, impermeable coating. As ordinarily applied, the finished coating is about ¾ of an inch thick.

The cost of ¾-in. plaster, applied as above, will be about six cents per square foot.

(II) MEMBRANES.

Membrane waterproofing consists of the formation of a mat or covering of waterproofing material over the surface to be waterproofed, made up of a number of layers of membrane united by a cementing material.

Being somewhat elastic and independent of the movement of the surface, this method offers a protection from the seepage of water through expansion or contraction joints and cracks in the masonry which cannot be secured by any other.

For this reason it is largely used for waterproofing subways, arches, solid floor bridges, retaining walls, basements, pits, etc.

It is also largely used in important structures in connection with some integral form of waterproofing as a precaution against seepage of water through cavities that may occur in the masonry.

Although waterproofing by the membrane method has been unsuccessful in many cases and many reports of failures are returned by the

railroad companies, the better methods of membrane waterproofing now in use are giving excellent results.

The character of the structure is frequently the greatest drawback to the life of the waterproofing. The greater the number of projections and irregularities in the surface to be waterproofed, the more the liability of leaks.

Many times the design of the structure is such as to make it impracticable to waterproof in a permanent manner. Sudden slopes or deep drops between the different elevations of the floor often cause the protection to slide, with a consequent tearing of the waterproofing. Often on railroad bridge floors the waterproofing is destroyed by the creeping of its protection under traffic; on arches or sharply inclined surfaces by its movement due to the settlement of the fill.

In many cases the labor employed is quite unskilled and the results are obviously poor.

Another factor in the success or failure of waterproofing is the state of the weather. In cold weather the heated materials cool too rapidly. In very damp or rainy weather it is impracticable to make a good job of waterproofing, unless some protection from the weather is provided.

Other causes of failure are the lack of free working space and interruption by traffic.

Any of these causes may lead to failure, even with the best materials.

MATERIALS.

The materials of membrane waterproofing and the combinations that have been used most successfully by the various railroads are as follows:

FELTS AND BURLAPS.

Wool felt impregnated with either asphalt or coal tar pitch.

Wool felt impregnated with either asphalt or coal tar pitch and skin coated with the same material.

Wool felt impregnated with coal tar pitch and reinforced with a thickness of cotton drilling cemented to the felt with coal tar pitch.

Asbestos felt impregnated with asphalt.

Burlap both plain and impregnated with either coal tar pitch or asphalt.

CEMENTING MATERIALS.

Mined or lake asphalts.

Petroleum asphalts.

Coal tar pitch.

COMBINATIONS.

Two (2) to three (3) layers of felt cemented together, used generally for damp-proofing and for the backs of retaining walls or foundations where no provision for a head of water is necessary.

Four (4) to six (6) layers of felt cemented together, used generally for railroad bridge floors, arches, tunnels, subways and for a protection from a head of water.

To add tensile strength to the waterproofing, the following combinations are commonly used:

One (1) middle layer of reinforced felt or burlap and four (4) layers of felt, all cemented together.

One (1) layer of felt, two (2) layers of burlap and two (2) layers of felt cemented together.

Three (3) layers of burlap and one (1) top layer of felt cemented together.

Combinations of coal tar pitch and asphalt treated felt or asphalt and coal tar treated felt should not be used as the materials will not combine.

In using burlap it is recommended that burlap impregnated with either asphalt or coal tar pitch be used, otherwise, owing to its nature, it is impracticable to prevent the absorption of moisture when the material is exposed to the weather. Moisture promotes rot and also greatly reduces, or, if present in any quantity, prevents the bond of the hot cementing material and its penetration of the pores of the burlap. On the other hand, the treating of burlap promotes the bond and penetration as the treating materials in the burlap are softened on the application of the hot cementing material, and the whole becomes united in one mass.

The use of burlap with cementing material, whose temperature on application exceeds 450 degrees Fahrenheit, is not recommended, as the higher temperatures are likely to result in burning and destruction of the burlap.

In many cases it is desirable to bond the waterproofing to the surface. This is not desirable in the vicinity of expansion joints or where there is likely to be a movement of the surface. At such points special provision must be made in the waterproofing to allow for expansion.

PROTECTION.

To protect the membrane from injury it is necessary to provide a covering of some hard material that cannot be penetrated by ballast, tamping picks nor by sharp stones.

Of the various methods, the following three have been the most widely used:

(1) Brick laid flat in the hot cementing material with joints poured with the same material, or brick laid in cement mortar.

On comparatively flat surfaces, brick is practicable with a bituminous binder, but on steep surfaces or slopes, the tendency to creep in hot weather makes it unsuitable. One great advantage of brick is that it can be laid quickly and easily under traffic. Brick, if used on large areas or on the extrados of an arch or on steep slopes, should be laid in cement mortar to prevent creeping.

(2) A cement mortar coating about two (2) inches thick, reinforced with wire mesh, forms a good protection and can often be used to better advantage where there is a tendency of the protecting materials to creep. This protection is recommended for arches and tunnels.

(3) A bituminous binder not less than one and one-quarter ($1\frac{1}{4}$) inches thick, consisting of asphalt or pitch mixed with sand, gravel or fine crushed stone and applied over the waterproofing, has often been successfully used. If this is used, it should be of such consistency in hot weather as to prevent runs and the stones forcing through the protection to the waterproofing. It is not recommended on steep slopes.

SPECIFICATIONS.

The following specifications for five-ply waterproofing is typical of those in use by the various railroads, and applies equally well to combinations of felts and burlaps or felts and reinforced felts:

"The surface on which the waterproofing is to be applied shall be dry and free from all sharp projections or irregularities of any character other than those shown on plans.

"If it is desired to secure the waterproofing to the surface this surface shall be given one (1) coat of hot cementing material mopped on uniformly, which coating shall be thin enough to penetrate the recesses, and in the case of concrete, to form a bond for the subsequent waterproofing coating. In order to insure the adhering of this coating it is advisable, in cold weather, to first heat the surface with hot sand, which is to be swept off as the cementing material is applied, or a priming coat of the cold cementing material which has been thinned with a suitable solvent may be applied.

"On this first coat shall be applied a heavy coating of hot cementing material, into which shall be laid, shingle fashion, two (2) layers of felt lapped one-half the width of the felt and cemented together with cementing material. The surfaces of the two-ply felt thus formed shall be mopped uniformly with hot cementing material and followed with three (3) layers of felt laid shingle fashion in this material and lapped two-thirds of its width. The surface of the five-ply of felt thus formed shall be given one (1) heavy coat of cementing material, making a five-ply waterproofing membrane all thoroughly saturated, cemented and bonded together.

"In the courses thus built up it is important to have the moppings of cementing material uniform, so that felt shall not touch felt at any point and to insure a surface free from all folds and pockets.

"At girder webs or around gusset plates, corners, or over column connections and expansion joints, the waterproofing membrane shall be reinforced with at least two (2) thicknesses of felt.

"Over the surface of the membrane shall be placed a protection of either brick, bituminous binder or concrete, plain or reinforced."

Cost of membrane waterproofing varies greatly with conditions.

A five-ply membrane waterproofing, with asphalt-treated felts cemented with asphalt, will cost from 25 cents to 45 cents per sq. ft., including a bituminous binder or brick protection and labor.

A five-ply membrane waterproofing, using four layers of coal tar pitch-treated felt and one layer of felt reinforced with cotton drilling, cemented with coal tar pitch, will cost from 20 cents to 35 cents per sq. ft., including bituminous binder or brick protection and labor.

A four-ply membrane waterproofing, using one layer of asbestos felt and three layers of impregnated burlap cemented with asphalt, including

$1\frac{1}{4}$-in. thick asphalt mastic protection and labor, will cost from 20 cents to 30 cents per sq. ft.

Cost of asphalt about $30.00 per gross ton.

Cost of coal tar pitch about $17.50 per gross ton.

Cost of asphalt treated felts from $1.00 to $1.25 per 100 sq. ft.

Cost of coal tar pitch treated felts about 25 cents per 100 sq. ft.

Cost of reinforced felt from $2.00 to $2.25 per 100 sq. ft.

Cost of asbestos felt about 70 cents per 100 sq. ft.

Cost of brick $8.00 to $12.00 per thousand.

(III) INTEGRALS.

The use of some material in small quantities, mixed with the concrete materials in order to make concrete watertight, is generally called the integral method of waterproofing.

I. INERT FILLERS.

The addition of a small amount of fine material to a rich concrete mixture with a well-graded aggregate, decreases the strength of the concrete. The effect upon leaner mixtures is to increase the impermeability of the concrete without decreasing its strength. Fillers used should not only be inert toward the action of the cement, but also to atmospheric conditions and to water.

Material containing organic matter should be avoided, owing to its deleterious effect upon the strength of the concrete.

In using inert fillers in mixing concrete only such materials should be used as have been thoroughly analyzed as to their chemical properties and effect upon the concrete both as to strength and chemical action. The amount of inert fillers used must be determined by careful tests.

The waterproofing effect of inert fillers depends upon the void-filling quality of the material used and upon the grade of workmanship insisted upon; the addition of a waterproofing compound to the concrete material coupled with poor workmanship will not assure watertight concrete.

It is an open question whether it is good engineering, especially on important structures, to omit precautions and methods of workmanship, which improve the quality of the resulting concrete in any respect, in order to reduce the cost and produce a somewhat inferior concrete which meets the present needs. There is a possibility that in gaging the amount of money to be spent in making concrete by the strength required, other factors may be lost sight of which may in time prove harmful to a structure which was supposed to be of the most durable construction.

There are numerous examples on record where structures have been built of concrete, in the too often used haphazard method of selecting proportions and aggregates and by inferor workmanship, due to lack of proper supervision, or lack of judgment and feeling of responsibility, with the idea that concrete is concrete, which will withstand

any usage as good masonry construction. This is a wrong conception of the importance of this class of work. The selection of proper proportions and well-graded aggregates of good quality, coupled with good workmanship, the proper consistency of the mix and the thoroughness of the mixing, depositing, compacting and spading are factors which must be considered and insisted upon if a good, dense, strong and durable concrete is to be obtained.

With such precautions employed, inert fillers or compounds used in the proper proportions, impermeable and good concrete should be obtained.

In presenting results of tests of waterproofing materials added to the ingredients of concrete, the proportions of the mixture are at times stated in two different ways. One method is to state that a certain proportion of waterproofing material was mixed with the cement and then the proportions of the test specimens are given as so much of the cement mixture to aggregate. Other tests are described in which an amount of waterproofing material equivalent to a certain percentage of the cement used is added to the concrete materials. The results of such tests cannot be correctly compared without reducing them to a common ratio between cement and aggregate.

When dry compounds are used from 1 to 2½ per cent. of the cement used are recommended by the manufacturers, while for the liquid compounds from 4 to 8 per cent. of the amount of water used is recommended by them.

The cost of concrete is increased by the addition of such materials from 80 cents to $1.20 per cubic yard for dry compounds and from 50 cents to $1.00 for the liquid compounds, per cubic yard of concrete.

2. ACTIVE FILLERS.

Compounds which are added to the concrete mixture and which react with certain of the constituents of the cement to form other compounds which will be inert and fill the voids are included in this class. In general these materials are soaps and saponifiable oils.

Inasmuch as the waterproofing effect of these materials depends upon a reaction which may or may not take place, objection has been made to their use. (See Appendix, p. 547.)

(IV) WATERTIGHT CONCRETE CONSTRUCTION.

The results of laboratory experiments, supplemented by many examples from practice, have shown that watertight concrete can be made without the use of coatings, membranes or integral compounds. It is reasonable to assume that the porosity of concrete in certain cases is due to the fact that it contains small air spaces or voids throughout its mass, which are connected to each other more or less irregularly, and through which water passes, due either to the presence of the hydrostatic head or to capillary attraction. At the time of placing the concrete, some space is occupied by water carrying in suspension fine

particles of cement. It is not necessary to assume that continuous capillary passages must be left in the concrete in order that as it dries the water may get out. It is probable that the excess of water passes out of the concrete in drying in such a state as to leave behind no pores through which water could again find access to the interior of the concrete or penetrate the structure.

The question of watertight concrete is then a problem of reducing the size and number of voids. Sands contain voids ranging from about 25 to 40 per cent. of the total volume of dry loose sand. The proportions of cement to aggregate required to make a mixture of the maximum density with sands of these extreme values, are about 1:1½ to 1:2½. Experience has demonstrated that mortars leaner than this are not suitable for work requiring considerable strength or density, so that the proportions used in ordinary engineering work are sufficiently rich to produce a watertight concrete, provided the aggregates possess the requisite qualities.

Samples of crusher run limestone show 37 per cent. voids for each of two specimens, one having a maximum size stone passing 2½-inch sieve, the second passing 1¼-inch sieve. A broken stone passing a 2½-inch ring and retained on a ⅜-inch screen had 46 per cent. voids. Feret found about 52 per cent. voids in samples consisting of stones of about one size, for each of three different sizes. A similar variation in the percentage of voids with graduation in sizes of particles is found with gravel, for screened gravel of approximately one size of particles 40 per cent. to 45 per cent., for a well-graded gravel containing sand 25 per cent.

The amount of voids in a mixture of aggregate and cement is the least when the cement is just sufficient to fill the voids in the aggregate, since the cement paste itself is less dense than the coarse material of the aggregate.

A slight deficiency in cement produces a porous concrete because the unfilled voids are large enough to permit the passage of water, while properly-made concrete containing an excess of cement, though it may be of lower density than the former, is impermeable after hardening since the voids in the cement paste are too small to permit the passage of water.

Tests have failed to discover substances which, added to the concrete materials, will increase the density of the cement paste which fills the interstices between the particles of the aggregates, hence it is not believed that improvement as regards impermeability of concrete containing sufficient cement can be made by the addition of any material to the concrete mixture.

Some engineers apprehend that grading and proportioning according to ideal requirements necessitates extreme care and considerable expense, and therefore reject this method of obtaining watertight construction for one of the integral compounds, which is in reality based upon the same principle, or the results of which are un-

certain as regards permanent impermeability and are detrimental to the strength of the concrete.

While it is true that concrete in which the amount of cement used is slightly in excess of the voids in the aggregate and in which the aggregate is so graded as to contain a minimum amount of voids, is an ideal mixture as regards density and strength, the requirements for watertight concrete do not demand the maintenance of exact proportions of this nature.

Experience has proved that materials, as supplied for large works, run uniformly enough to permit the proportioning and grading to be maintained at such a degree of excellence as to insure watertight construction at a very small expense for testing.

The following abstract from the results of laboratory tests made by the United States Bureau of Standards, Technologic Paper No. 3, are here quoted:

"These tests show that the permeability of concrete was not dependent entirely upon the quantity of cement used in proportion to the total aggregate, but depended also upon the ratio of coarse aggregate to fine aggregate. It will be observed in the case of sand No. 4, that the 1:1½:7½ proportion was decidedly more impermeable than the 1:2:4 proportion, although the former contains considerably less cement in proportion to aggregate."

Tests designed to show the effect of waterproofing materials, especially such as are added as fillers, should present a granulometric analysis of the aggregate, as comparisons are valueless without such information. It is to be expected that tests on mortar in which a sand was used, having a deficiency of fine particles would show increased impermeability and increased strength upon the addition of a small amount of fine material. On the other hand, if the aggregate already contains as much fine material as it requires, addition of a fine material as waterproofing may be expected to decrease the strength and have no beneficial effect as a waterproofing material.

The method of proportioning the aggregate by mechanical analysis, which is described by Taylor & Thompson as exact and scientific, is recommended. The granulometric analysis requires a very inexpensive equipment, and a complete analysis of an aggregate may be made in less than one hour's time. By its use definite data may be obtained upon which to base conclusions as to the necessity of and method of improving the concrete mixture.

In discussing the use of exterior coatings as against impermeable construction, the point is often advanced that although there is no doubt that watertight concrete can be made, the watertightness is of no avail when cracks occur in the structure.

The subject of cracking is one of design. Cracks are caused by failure to properly provide for primary stresses to which the structure is subjected, by faulty details, by settlement of foundations, by shrinkage of concrete when hardening in air, and by stresses developed in the concrete due to temperature changes.

Where concrete is to be deposited under circumstances which make it impracticable to construct watertight concrete, a special form of waterproofing should be provided. (See Appendix, p. 550.)

DRAINAGE.

The first requisite in designing any structure when water is to be kept out from the interior or from beneath, is to provide means of getting rid of the water as directly and as quickly as possible. Methods of providing drainage differ with the class of the structure.

During the construction of basements and pits, drainage can be maintained by pumping, and permanent drainage should be provided whenever a free outlet can be obtained.

Drainage of arches and culverts is provided by sloping the extrados to the back of the abutments and to the piers, placing downspouts at piers and drain pipes behind abutments.

Drainage of retaining walls, abutments and subway walls is provided by one or more lines of drain pipes, placed at different elevations along the back of the walls.

In tunnels the extrados of the arch may be provided with sufficient slope to facilitate the flow of seepage water to the sidewalls. The back filling consists of porous materials, which will permit the ready passage of the water. Side-drains and connecting under-drains should be provided.

The drainage of subaqueous tunnels differs from the general problem of drainage, and is not concerned with waterproofing, in that it is a problem of handling water on the inside of the tunnel. This is usually accomplished by pumping from sumps.

The foundations of masonry reservoirs should be drained to insure the stability of the structure.

The solid floors of steel or reinforced concrete bridges may be drained by sloping the finished surface of the floor from the center to each end, and carrying the water away back of the abutments, or the water can be carried away by downspouts at the intermediate points or supports.

Probably the commonest method of draining solid-floor bridges is to slope the deck to one abutment or from a summit to both abutments. A continuous waterproofing layer extends over the deck and the top of the abutments and extends down over the back of the abutments to prevent the seepage of water at the bridge seat.

The surface of the waterproofing and its protection must have sufficient grade to carry away surface water. In the case of bridge floors, it is recommended that this grade be not less than six (6) inches in one hundred (100) feet. It is customary, when bridges are on sufficient grade, to have the waterproofed surface at the same grade, the water being carried down over the back wall of the lower abutment where drainage is provided by coarse backing and open-joint drains.

An objection to this method of drainage is made by some who find that in the spring, when the surface ice and snow melt and the filling

back of the abutments is still in a frozen condition, the water does not escape freely, but accumulates and eventually seeps through at the end of the bridge and flows over the face of the abutment. Another objection is that in bridges having supports at curb lines and in the middle of the street, whether of flat slab construction or of steel troughs filled with concrete, cracks in the waterproof covering and in the concrete filling are likely to appear where joints are not provided over these supports, and where joints are provided, trouble is likely to be experienced in preventing the seepage of water.

When the troughs of steel bridges run transversely to the track and the filling in the troughs is omitted, the individual troughs may be drained through outlets in the bottom of the troughs into a drainage gutter suspended beneath the deck. These gutters may empty into pipes which run through the abutments and empty outside the embankment. Difficulty is found in obtaining a seal between the waterproofing and the drain pipe or opening in the trough.

When the troughs of solid floor steel bridges run parallel with the tracks, the water is usually carried over the abutments as in the concrete floor bridges.

A method sometimes used on solid-floor bridges in which the deck is filled up above the top of the steel with cement or bituminous concrete is to divide the floor of the bridge into rectangular sections, each of which is sloped to a drain pipe at one corner which carries the water through a downspout at one of the supporting columns.

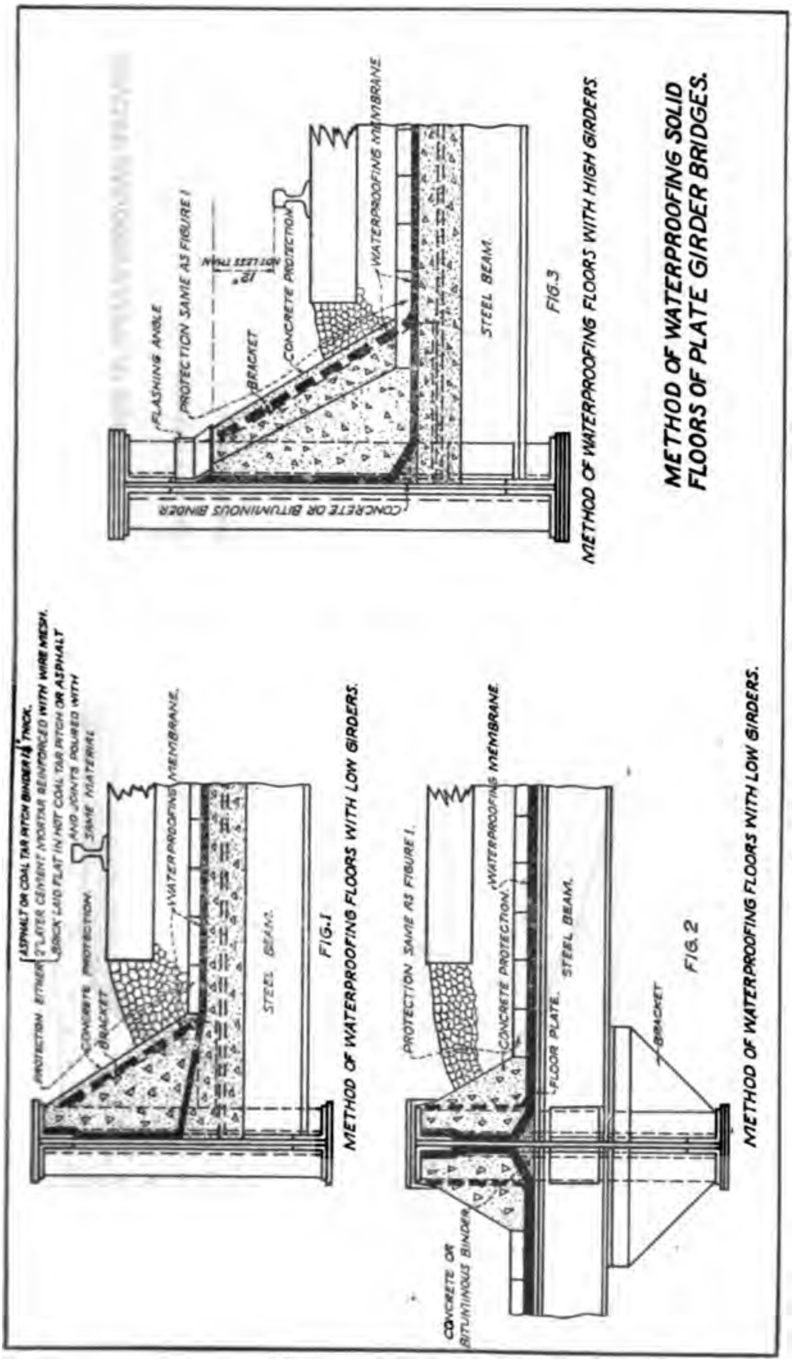
Much difficulty has been experienced with all types of waterproofing on steel bridges in preventing the leakage of water along the webs of girders. Although the concrete filling of the deck may be carried up above the top of the rail and great pains may be taken in providing a joint with a waterproofing material between the girder web and the concrete, leaks usually develop along the girder.

Several bridges have been built in which a special flashing angle or Z-bar extending the full length has been riveted to the inside of the girder to prevent the flow of water down the web of the girder. By carrying the concrete filling up underneath the outstanding leg of the flashing angle or Z-bar an efficient flashing is obtained. Good results have been obtained in the case of through girder bridges by carrying the concrete filling up under the top flange of the girder.

In considering the conclusions presented in Bulletin 64 in regard to reinforcing over supports, the following remarks of President Armstrong, of the Western Society of Engineers, are of interest:

"In large railroad structures it is impracticable to reinforce concrete so that there will be no cracks over a line of supports; good engineering would not permit such practice. It would be better to allow the concrete to crack or to leave a joint there, and then provide some means of keeping out the water. In the lighter structures, it is practicable to reinforce the concrete so that the reinforcement will prevent cracks at supports."

A joint in the waterproofing which will allow of movement of the ends of adjacent spans at supports is believed to be necessary. The

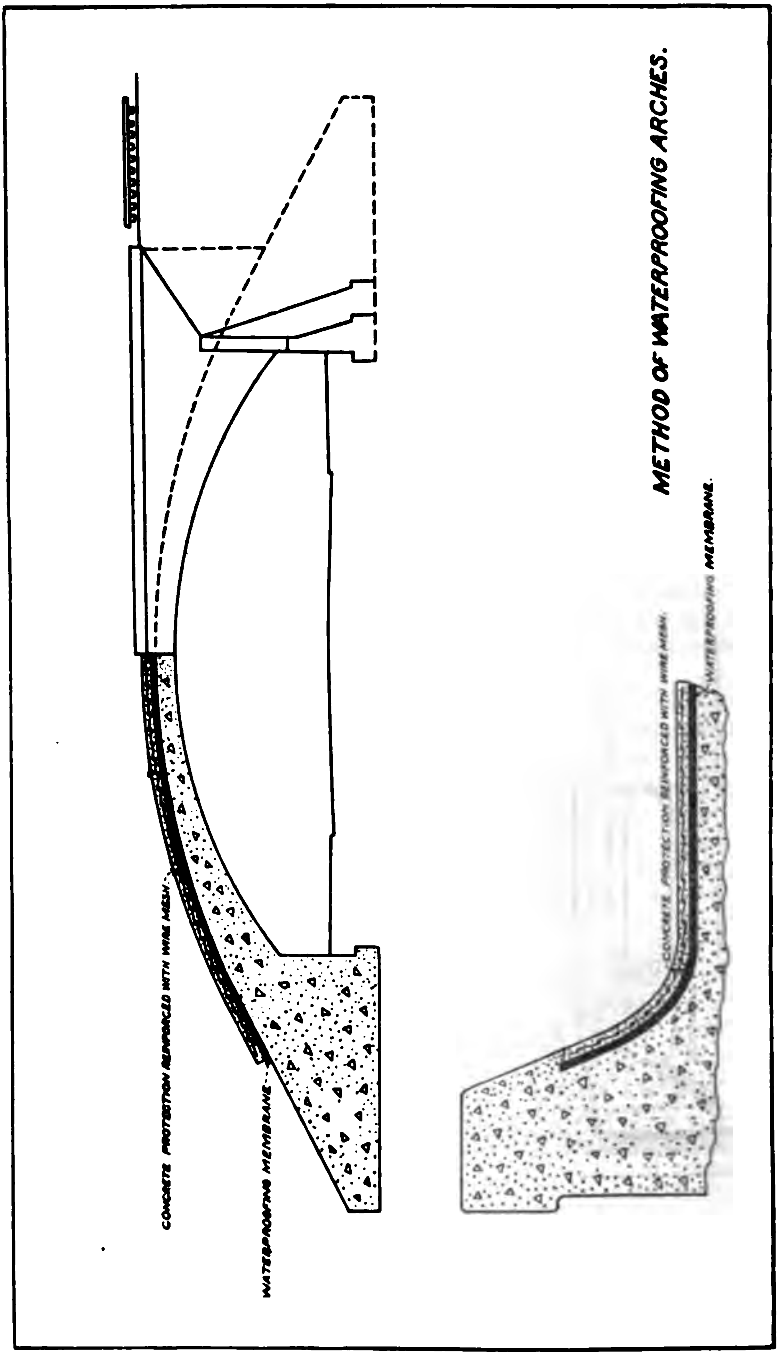


METHOD OF WATERPROOFING FLOORS WITH LOW GIRDERS.

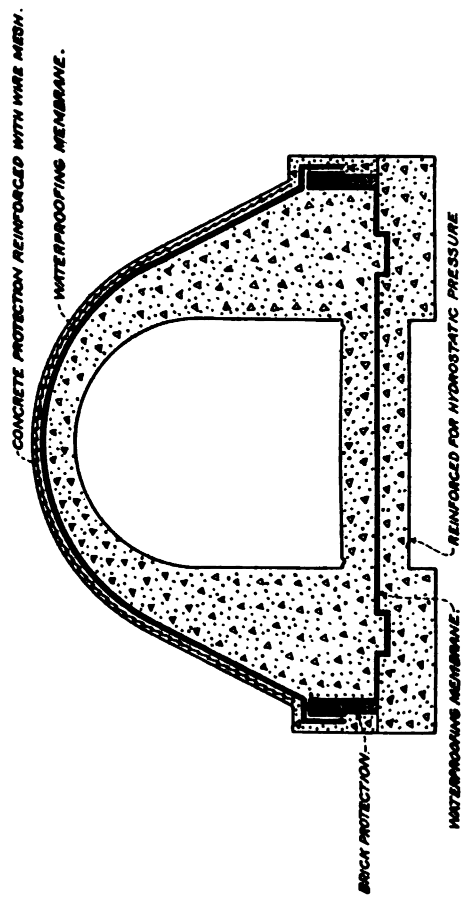
METHOD OF WATERPROOFING FLOORS WITH LOW GIRDERS.

METHOD OF WATERPROOFING FLOORS WITH HIGH GIRDERS.

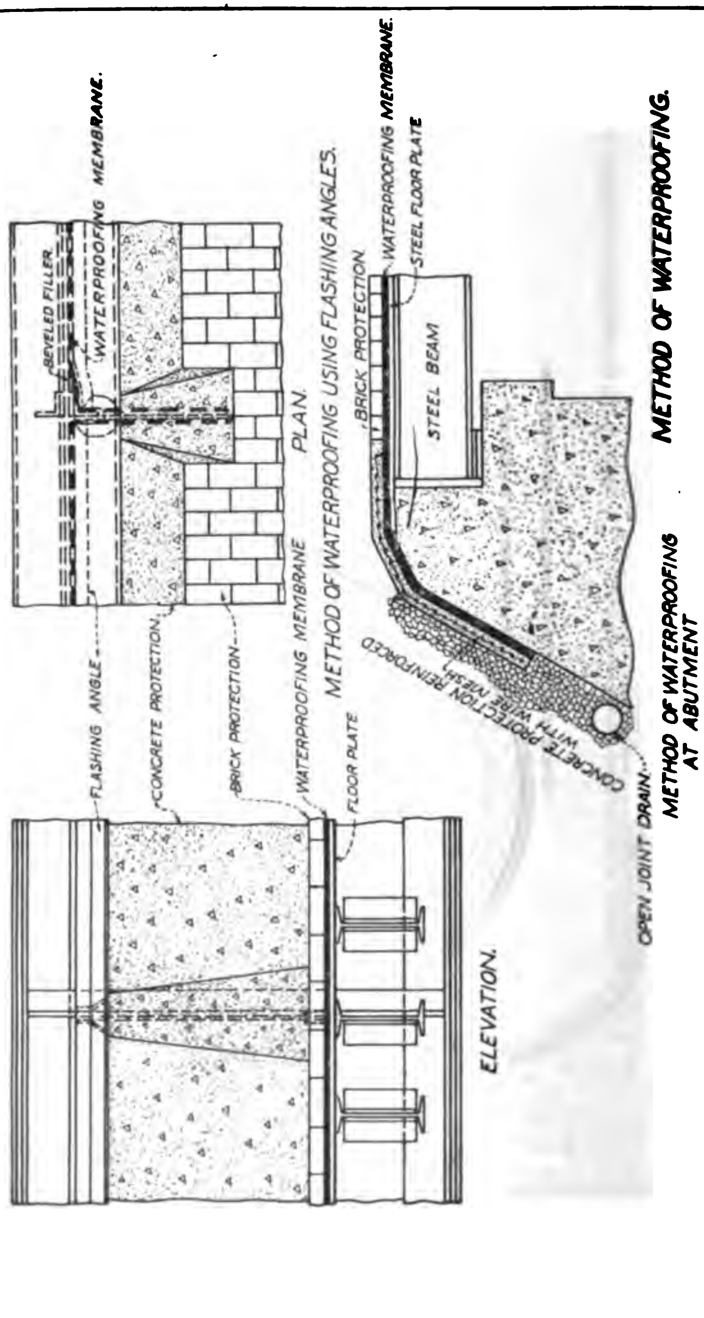
METHOD OF WATERPROOFING SOLID FLOORS OF PLATE GIRDER BRIDGES.



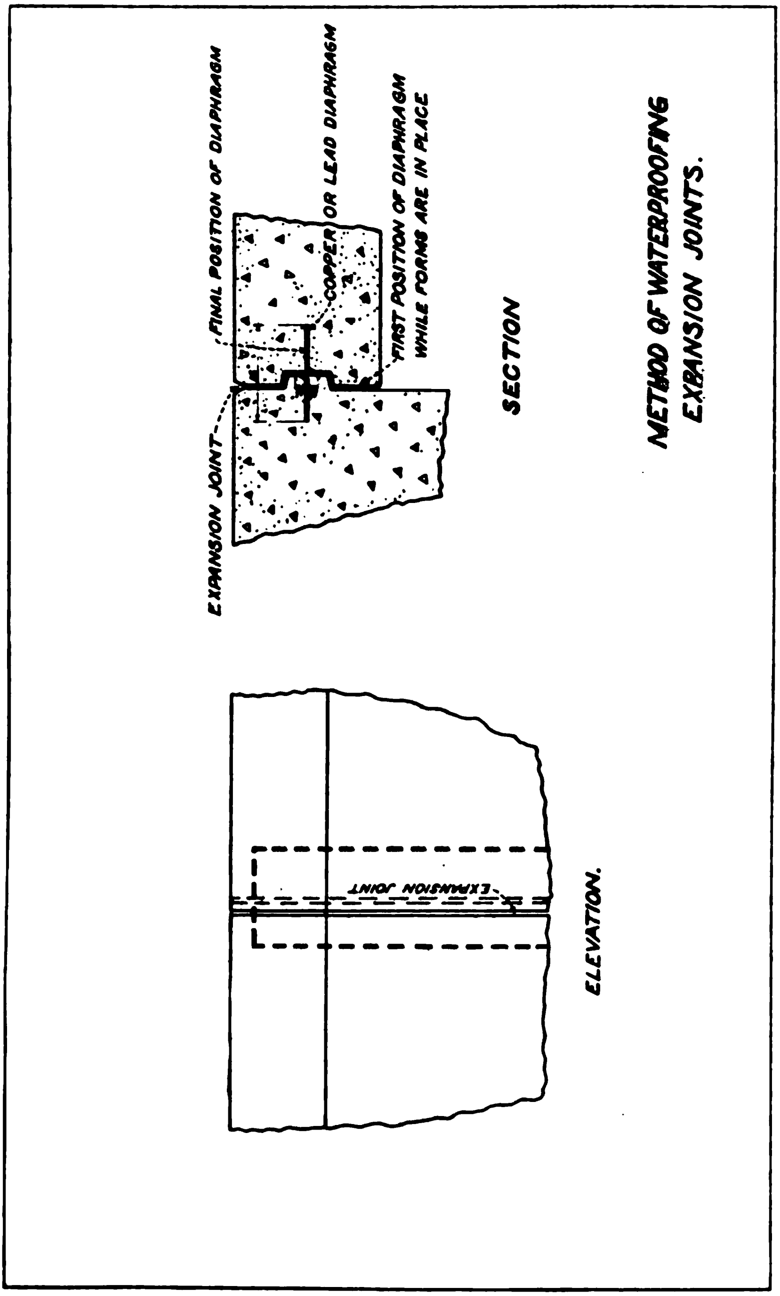
METHOD OF WATERPROOFING ARCHES.



METHOD OF WATERPROOFING SUBWAYS.



METHOD OF WATERPROOFING.



METHOD OF WATERPROOFING
EXPANSION JOINTS.

use of a metal flashing between concrete slabs over joints has been used.

When the steel troughs run transversely to the track, a slight movement under traffic is to be expected at the connection of the troughs to the girders. Consequently, it would seem necessary to keep the water away from these connections by means of flashing and providing sufficient slope toward the center of the floor, adjacent to the girders.

Diagrams showing method of waterproofing various structures are given in this report.

CONCLUSIONS.

(1) Watertight concrete may be obtained by proper design, reinforcing the concrete against cracks due to expansion and contraction, using the proper proportions of cement and graded aggregates to secure the filling of voids and employing proper workmanship and close supervision.

(2) Membrane waterproofing, of either asphalt or pure coal-tar pitch in connection with felts and burlaps, with proper number of layers, good materials and workmanship and good working conditions, is recommended as good practice for waterproofing masonry, concrete and bridge floors.

(3) Permanent and direct drainage of bridge floors is essential to secure good results in waterproofing.

(4) Integral methods of waterproofing concrete have given some good results. Special care is required to properly proportion the concrete, mix thoroughly and deposit properly so as to have the void-filling compounds do the required duty; if this is neglected, the value of the compounds is lost and their waterproofing effect destroyed. Careful tests should be made to ascertain the proper proportions and effectiveness of such compounds.

Integral compounds should be used with caution, ascertaining their chemical action on the concrete as well as their effect on its strength; as a general rule, integral compounds are not recommended, since the same results as to watertightness can be obtained by adding a small percentage of cement and properly grading the aggregate.

(5) Surface coatings, such as cement mortar, asphalt or bituminous mastic, if properly applied to masonry reinforced against cracks produced by settlement, expansion and contraction, may be successfully used for waterproofing arches, abutments, retaining walls, reservoirs and similar structures; for important work under high pressure of water these cannot be recommended for all conditions.

(6) Surface brush coatings, such as oil paints and varnishes, are not considered reliable or lasting for waterproofing of masonry.

Appendix B.

(I) COATINGS.

LINSEED OIL PAINTS AND VARNISHES.

The following information is from Technologic Paper No. 3, U. S. Bureau of Standards, Tests of the Absorptive and Permeable Properties of Portland Cement Mortars and Concretes, and Tests on Dampproofing and Waterproofing Compounds and Materials, 1911:

"Compounds in this class differ in no wise from the ordinary enamel paints, which are usually characterized by hardness and brittleness due to the comparatively large amount of hard resins and the small amount of linseed oil. Linseed oil is constantly undergoing changes due to oxidation and, in the presence of alkali, its life is still further decreased owing to the saponification which takes place in the presence of the latter. Nearly all these coatings softened under the influence of water, thus showing that saponification was taking place. By putting more resin in the material, the manufacturer puts more of a stable compound in it, as opposed to the more unstable material linseed oil. In respect to both oxidation and saponification, the resins are more stable. To replace all or nearly all of the oil by resin would give a very brittle, inelastic coating, which is so little desired.

"Some manufacturers have added Portland cement to varnishes and placed them on the market, but these decompose so quickly, the oil reacting with the cement, that they were withdrawn.

"No one special pigment was found in samples tested. The volatile material or thinner used in these compounds was also that common to ordinary paints or varnishes. Some of the paints could not be distinguished by chemical analysis from any of the other similarly colored paints on the market to be used for general purposes. Paints carrying petroleum oil, would, after the evaporation of the volatile thinners, leave the petroleum filling the surface pores. Under any considerable head of water, it would be forced out."

A. S. Cushman, Director, Institute of Industrial Research, Washington, D. C., in Am. Soc. for Testing Materials, Vol. 10: "The reason why some treatment should be necessary before applying paint coating to the surface of concrete must be apparent to everyone. When Portland cement sets, a certain amount of lime is set free in a hydrated condition, as calcium hydroxide. This is a strong alkali and tends to saponify the oil in the paint coating and thus destroy it. Zinc sulphate is very well adapted for preliminary treatment of the concrete surface owing to the fact that when zinc sulphate is brought into contact with calcium hydroxide, a chemical reaction takes place which results in the formation of calcium sulphate and zinc hydroxide. After the concrete surface is dry, a solution of zinc sulphate and water, equal parts by weight, should be applied with an ordinary bristle brush and allowed to dry from 48 to 72 hours. After the surface has become

thoroughly dry again, it will contain within its pores a mixture of gypsum and zinc oxide; these materials have no bad influence on linseed oil, and in fact are frequently used as paint pigments."

Mixtures of various Bitumen with Linseed Oil, etc., information from Tech. Paper No. 3: "This class covers a large variety of mixtures. The makers seem to have had one purpose in mind in making these, however, to make the materials more elastic by the addition of a drying oil, as linseed oil. It is a question if they have not sacrificed durability by this addition, since it is very likely that bitumen alone on the concrete would last longer and be more inactive than the readily oxidizing and very active and drying oils."

ASPHALT.

The following information is taken from "Roads and Pavements," by I. O. Baker, and from other sources:

"Recent investigations are inclined to class all components of asphalt under two heads only, the active and the inert. The active element is that part which is easily melted by heat, is readily soluble in ether or naphtha and is highly adhesive and cementitious; while the inert material is the hard and brittle part which is not readily melted by heat and which adds nothing to the cementitious properties of the asphalt. The ratio in which the active and the inert constituents are combined is the true index of the value of asphalt for use as a cement.

"Crude and also refined asphalts from different localities differ widely in consistency, in susceptibility to changes of temperature and to changes by age, in stability at high temperatures, cohesiveness, adhesiveness, elasticity, etc. There is no recognized standard for testing the physical properties of asphalt and the results of such tests are usually stated in terms so general as to be of no scientific value. As a rule, tests of the physical properties are useless except perhaps in comparing two asphalts tested at the same time, under the same conditions.

Composition of Trinidad Asphalt.

Components.	Crude Hard Lake Asphalt.
Bitumen soluble in carbon bisulphide	38.15 per cent.
Earthy matter	26.38 per cent.
Vegetable matter	7.63 per cent.
Water	27.85 per cent.
	Refined Hard Lake Asphalt.
Bitumen soluble in carbon bisulphide	53.87 per cent.
Earthy matter	36.56 per cent.
Vegetable matter	10.57 per cent.

Bermudez Asphalt.

Composition of the Crude Asphalt.

Bitumen soluble in carbon bisulphide	93.54 per cent.
Earthy matter	2.16 per cent.
Vegetable matter	1.15 per cent.
Water	3.15 per cent.

"In manufacturing asphaltic cement, the Bermudez asphalt requires much less of the fluxing agent than does the Trinidad on account of the large amount of oil contained in the former.

"Maltha (Cal.) refined product contains an average of 98.26 per cent. of pure bitumen and 1.74 per cent. of mineral matter.

Solid California Asphalt.	Average Composition (crude.)
Bitumen soluble in carbon sulphide	59.15 per cent.
Earthy matter	39.75 per cent.
Vegetable matter	1.10 per cent.

"There are also some soluble salts present in asphalts in small quantities which possibly may help to explain the fact that asphalt is acted upon by standing water.

"*Asphaltic Cement.*—Asphalt is so hard that before being used it is necessary to soften it by the admixture of oil. A selection of the proper fluxing agent for the harder asphalts is a very important matter. The properties required of an asphaltic flux are:

"(1) It should contain no material volatile under 300 degrees Fahrenheit, as otherwise the volatile matter will be given off while it is being heated. (2) The flux should be as fluid as possible, in order that the greatest softening effect may be produced by the least quantity, as ordinarily the fluxing agent is expensive. (3) The softening agent should be chemically stable and not lose its fluidity by molecular change. (4) The fluxing agent should dissolve the asphalt and not simply form a mechanical mixture with it, and therefore the fluxing agent should dissolve the asphaltene. There are two general classes of asphaltic flux in common use: (1) Petroleum residuum or artificial bituminous fluxes and (2) Malthas or natural bituminous fluxes. The first is composed of liquid paraffin and the second of fluid natural bitumens of the same nature as asphalt. There are two forms of each in more or less general use. There are, therefore, four fluxing agents, viz.:

"(1) Residuum from the paraffin petroleum of Pennsylvania.

"(2) A specially prepared paraffin—petroleum residuum known as Pittsburgh flux.

"(3) Residuum from the asphaltic petroleum of California.

"(4) Maltha.

"Until recent years the first was the only fluxing material in use, but at present all four are in more or less common use.

"*Paraffin Petroleum Residuum.*—Judging from the physical properties of this residuum and its chemical relations to asphalt bitumen, it is not a desirable flux.

"*Pittsburgh Flux.*—This is made by heating paraffin petroleum residuum with sulphur, which favorably changes the paraffin and has been used to a limited extent.

"*Asphalt Petroleum Residuum.*—California petroleum is an excellent solvent of asphalt and in recent years has been much used as a fluxing material.

"*Maltha.*—This is unsuitable for use as the fluxing agent for asphalt, as it has no fluxing effect upon the asphalt to which it is added.

"*Petroleum Residuals.*—The petroleums found in the United States vary in quality according to their location.

"The Pennsylvania oils are rich in paraffins and in the lighter and more valuable illuminating oils and naphthas. Most of the California oils are practically free from paraffins and have comparatively small quantities of the illuminating oils. They are darker in color, have a greater specific gravity and have what is known as an asphaltic base. The oils found in the intermediate fields have qualities varying between the two extremes.

"As compared with asphalt, tar more easily loses its cementing qualities by vaporization and oxidation. The particular method of distinguishing asphalt and coal tar, therefore, to the layman, is the odor. The tar emits a sharp odor while both the crude and the refined asphalt when cold give a weak clay-like odor and must be rubbed to obtain the distinctive bitumen odor. If tar is mixed with asphalt the presence of 25 per cent. will be revealed by the odor. When being laid, tar gives off a bluish vapor while asphalt emits a white vapor. Expert analysis is necessary to detect the presence of tar when mixed with asphalt in small quantities. The following method will certainly detect 5 per cent. to 7 per cent. of tar: Extract the bitumen with carbon disulphide, filter, evaporate to dryness and heat the residue until it can be ground to a dry powder; 0.1 of a grain is treated with 5 c.c. of fuming sulphuric acid for 24 hours and is then mixed by continuous stirring with 10 c.c. of water. If coal tar be present, the solution will be of a dark brown or blackish tint; if not, the solution will be of a light yellowish color.

"Tars are sometimes employed for fluxing purposes, but they do not mix easily with the asphalt. As asphaltic compounds age, they tend to become brittle and hard, losing their elasticity and combining power. Poor fluxing hastens this process."

ASPHALT SPECIFICATIONS.

Specifications for asphalt waterproofing, Chicago & Northwestern Railway, by W. H. Finley, in Journal, Western Society of Engineers, June, 1912:

"Asphalt shall be used which is of the best grade, free from coal tar or any of its products, and which shall not volatilize more than 0.5 per cent. under temperature of 325 degrees Fahrenheit, for seven hours.

"It must not be affected by 20 per cent. solution of ammonia, a 25 per cent. solution of sulphuric acid, a 35 per cent. solution of hydrochloric acid, or by a saturated solution of sodium chloride. It should allow no hydrolytic decomposition when subjected for a period of ten hours to hourly immersions in water, with alternate rapid drying by warm air currents.

"For metallic structures exposed to the direct rays of the sun, the asphalt must not flow under 212 degrees Fahrenheit, nor become brittle at 0 degrees Fahrenheit, when spread thin on glass.

"For structures under ground, such as masonry arches, abutments, retaining walls, foundations, walls of buildings, subways, etc., a flow point of 180 degrees Fahrenheit, and a brittle point of 0 degrees Fahrenheit, will be required.

"A mastic made from either grade of asphalt by mixing it with sand in the proportion of 1 asphalt to 4 sand must not perceptibly indent when at a temperature of 130 degrees Fahrenheit, under a load of 20 lbs. per sq. in. It must also remain pliable at a temperature of 0 degrees."

From discussion on above by Clifford Richardson:

"Referring to the above specifications, it is claimed that they call for a material of much too high a melting point, and on this account, necessarily a very short material and one lacking in ductility and adhesiveness. A material of a lower melting point and one that is more adhesive possesses greater self-healing properties, that is to say, of uniting if a crack forms in the concrete over which it is placed and by any chance fractures the waterproof coating."

Specifications proposed by Clifford Richardson:

"(1) *Asphaltum.*—In order to demonstrate that the asphaltum is free from coal tar, its distillate, obtained upon destructive distillation, must be completely insoluble in dimethyl sulphate.

"In order to demonstrate that the asphaltum is essentially a genuine natural asphaltum and not largely a petroleum residue, it shall have a specific gravity, at 77 degrees Fahrenheit, greater than unity, and shall not contain over 1.0 per cent. paraffin scale as determined by the Holde method.

"(2) *Purity.*—In order to demonstrate the percentage of bitumen in the asphaltum, and to regulate the uniformity of the material, it shall be soluble to the extent of at least 95 per cent. in carbon disulphide.

"(3) *Consistency.*—In order to demonstrate that the asphaltum is of the proper degree of consistency, it must, when tested for 5 seconds at 77 degrees Fahrenheit, with a No. 2 needle, weighted with 100 grams, have a penetration of at least 7.5 mm. and not more than 10.0 mm.

"(4) *Viscosity.*—In order to demonstrate that the asphaltum has a sufficiently low melting point and a degree of fluidity to be conveniently melted for use, and possesses suitable flowing and self-healing properties, it shall have a viscosity of not more than 10 minutes at 150 degrees Fahrenheit, as determined by the float test apparatus, manufactured by Howard & Morse, Brooklyn, N. Y.

"(5) *Cementitiousness.*—In order to demonstrate the cementitious or adhesive character of the asphaltum and to preserve the proper balance between its adhesive and cohesive qualities, such asphaltum shall have a ductility between 25 and 100 cm. at 77 degrees Fahrenheit, according to the District of Columbia standard.

"(6) *Stability.*—In order to demonstrate that the asphaltum is of a sufficient stability to insure against loss of consistency upon being subjected to working heat, it shall meet the following test:

"When 50 grams of the asphaltum are heated in a dish 2¼ in. in diameter, for seven hours at 325 degrees Fahrenheit, the loss shall not

exceed 3 per cent., and the penetration of the residue shall not be reduced more than 50 per cent. from its original consistency.

"(7) *Durability.*—In order to demonstrate that the asphaltum is unaffected by water, a thin film of such asphaltum, when coated on glass and immersed in fresh or salt water at atmospheric temperatures for an indefinite period of time, must not disintegrate.

"(8) *Safety.*—In order to insure safety of operation the asphaltum must not flash below 350 degrees Fahrenheit, when tested in the Cleveland cup.

"(9) *Standard.*—Any asphaltum to be eligible for use under these specifications must be in all respects equal in quality to refined Bermudez Lake asphalt, but whether the asphaltum is manufactured of refined Bermudez Lake asphalt or otherwise, it shall not be considered as complying with these specifications unless it complies with each and all of the tests herein above specified."

Specifications for waterproofing Chicago River tunnel:

"(38) The asphalt should be the best Assyrian, Cuban or Alcatraz, free from coal tar or any of its products, and must not volatilize more than 0.5 per cent. under a temperature of 300 degrees Fahrenheit for ten hours. It must not be affected by a 20 per cent. solution of ammonia, 25 per cent. solution of sulphuric acid, a 35 per cent. solution of muriatic acid, nor by a saturated solution of sodium chloride. It shall show no hydrolytic decomposition when subject for a period of ten hours to hourly immersions in water with alternate rapid drying by warm air currents.

"(39) The asphalt must not flow under a temperature of less than 200 degrees Fahrenheit, nor become brittle at 0 degrees Fahrenheit when spread thin on a sheet of glass. A mastic made with equal parts of asphalt and bank sand or marble dust must not indent below a temperature of 100 degrees Fahrenheit, when subject to a load of 20 lbs. per sq. in.; it must also be pliable at a temperature of 0 degrees Fahrenheit.

"(40) The waterproofing course shall consist of two courses of brick laid flat in hot asphalt mastic. The joints of the brick work shall be at least one inch thick. The brick shall be carefully laid and not shoved along nor into the mastic. After the first course of brick is laid, it shall be flooded with hot asphalt mastic, care being taken to thoroughly cover the brick and fill all joints. The second course of brick shall then be placed as above specified and then flooded with hot asphalt so there will be at least one inch cover of asphalt mastic over all brick in every course.

"(41) The compound or mastic used may vary according to the nature of the work or time of placing, but in general it will consist of one part by weight of asphalt to one part sand or marble dust, these to be thoroughly stirred and mixed while heating and applied at a temperature of not less than 375 degrees Fahrenheit. In joining old or hardened

"(42) No waterproofing shall be used or placed until the concrete has been fully dried, nor shall any waterproofing be done in damp or rainy weather.

"(43) Waterproofing shall be paid for on the basis of actual amount measured in place at a unit price per square foot, mentioned in the proposal.

"(44) Brick used in waterproofing shall be thoroughly dried and shall be heated before using, if this becomes necessary."

A very interesting exhibit of bituminous waterproofing material is to be seen in the office of the Harbor and Subway Commission, City Hall Square Building, Chicago. Specimens of waterproofing removed from the old Chicago River tunnels are over 40 years old, the material having been applied about 1869.

At the time of the construction of the LaSalle and Washington Street tunnels in 1869, the city was supplied with a bituminous waterproofing material which was being used on fortifications under construction at Newport News, and which was supplied to the city at cost by the Government. The waterproofing of these tunnels consisted of a layer of brick laid in asphalt. The samples shown, which were several inches square and about ½ in. thick, were pliable, and could be easily indented with the fingernail at room temperature and seemed to have a fair amount of strength. Upon ignition and upon rubbing with the hand the material gave off the characteristic odor of asphalt. A sample of material, which has been in a tin can for two years, has conformed to the shape of the vessel, that is, it apparently melted down. The condition of this material would seem to indicate that under the pressure to which it is subjected in use, it would be self-heating and, considering the age, over 40 years, the condition seems remarkably good. It must be remembered that up to the time of the opening of the drainage canal, the Chicago River was an open sewer, carrying practically all the sewage and wastes of the city of Chicago.

A specimen of pitch used in some of the waterproofing done several years ago was shown, and was apparently in excellent condition.

The bids on waterproofing one of the recently constructed Chicago River tunnels, according to the specifications given, including the protective covering of 8 in. of concrete, varied from 50 to 70 cents per sq. ft. The waterproofing of these tunnels by the methods described has proved very efficient. The principal difficulty has been that, owing to the nature of the reconstruction work, there have been places where no waterproofing could be applied, and there has been a great deal of work that had to be in small pieces and joined to other work. The results obtained, however, have been very satisfactory.

Armstrong, in Western Society of Engineers, on New Passenger Terminal, Chicago & Northwestern Railway, Chicago, Ill.:

"There were three classes of waterproofing work, each differing from the others in certain particulars:

"(1) On passenger platforms in train shed.

"(2) On tracks in train shed, being the space between platforms.

"(3) On ballasted track floors.

"(1) Waterproofing on passenger platforms consisted of an asphalt mastic coating 1½ in. thick on top of the concrete of the platform, to serve as a wearing surface in addition to its waterproofing qualities. The concrete was first given a coat of liquid asphalt paint, applied cold. The mastic used was the manufactured product of the Standard Asphalt & Rubber Co. It was brought on to the work in blocks and melted in specially designed boilers with the addition of a small percentage of flux.

"After the mastic was thoroughly melted and mixed with the flux, grit, in the form of washed torpedo gravel or granite screenings, was added to the mixture, the amount of grit varying from 50 per cent. to 60 per cent. of the mass. The mixture was thoroughly stirred with iron stirring rods and brought to a temperature of 450 degrees Fahrenheit. It was then spread over the surface of the floor and rubbed down with wooden floats. The mastic was applied in two layers, each ¾ in. thick. The first layer was mixed with torpedo sand and the second layer with granite screenings, to reduce the slipperiness of the surface. The second layer was sprinkled with fine sharp sand while still warm and soft, and thoroughly rubbed to a true smooth surface. On top of this, dry Portland cement was sprinkled and the rubbing continued until the mastic had quite hardened."

Information concerning the use of asphalt for waterproofing has been published in the American Railway Engineering Association Proceedings as follows:

Market Street Subway, Philadelphia....................Vol. 11, Part 2
Chicago, Burlington & Quincy Railroad..................Vol. 11, Part 2
Baltimore & Ohio Railroad..............................Vol. 11, Part 2
Nashville, Chattanooga & St. Louis Railway.............Vol. 12, Part 1
Chicago & Northwestern Railway.........................Vol. 12, Part 1
Central Railroad of New Jersey.................Vol. 13, Vol. 12, Part 1
Chicago, Rock Island & Pacific Railway............................
..........................Vol 11, Part 2; Vol. 12, Part 1; Vol. 13
Michigan Central Railroad....................................Vol. 13
Union & Southern Pacific System..............................Vol. 13
New York Central & Hudson River Railroad.....................Vol. 13

American Railway Engineering Association, Bulletin 64, June, 1905.

In a paper on the Chicago River Tunnels, presented before the Western Society of Engineers, November, 1911 (Journal, Vol. 16, No. 19), by William Artingstall, the following information is given regarding the waterproofing of the Chicago River tunnels:

"The roof of the Van Buren Street tunnel, reconstructed in 1907, consists of concrete jack arches between steel cross girders 4 ft. 3 in. c. c. Over the entire roof and extending up into the bulkheads over the ends of the river section of the new roof, was laid a waterproofing course of brick embedded in and flushed with hot asphalt compound. This is protected by a 12-in. course of concrete.

"The concrete in the jack arches was mixed wet and thoroughly puddled. Concrete was allowed to set and thoroughly dry for two weeks before starting the waterproofing course.

"The specified waterproofing was one course of brick and a mixture of asphalt and gypsum, but so much trouble was encountered by foaming that this mixture had to be abandoned and a mixture of asphalt, asphaltic cement and marble dust substituted. This retained the heat better, gave no trouble in the boiling pan, and adhered better to the brick. But like the other, the new mixture did not adhere to the concrete. To remedy this feature, a second course of brick, with 1½-in. joints, was embedded in the filler course of asphalt and the upper parts of the joints filled with cement grout. The waterproofing was finished February 16, 1907.

"In the reconstruction of the Washington Street tunnel in 1906, the waterproofing used on the roof consisted of a mastic of asphalt, asphaltic cement and marble dust, the amount of any one being governed by the requirements of the particular location or condition. In general, however, the asphalt was about 50 per cent. of the entire mixture. An inch layer of the mixture was spread over the roof and hard sewer brick was immediately imbedded therein, with joints not less than one-half inch, which were then flooded with a thinner mixture of the same mastic.

"In the reconstruction of this tunnel in 1909, the waterproofing course used on Section 1 of the tunnel (lying between Clinton and Canal streets) was brick laid in asphalt.

"It is noted that in the construction of the old LaSalle Street tunnel, built in 1869-1871, the outer course of brick in the arches was laid in asphalt, instead of simply being covered with a layer of asphalt."

In discussing the design of the new LaSalle Street tunnel, Mr. Artingstall makes the following remarks:

"On account of our assumption of open cut work, the tunnel at an early stage must necessarily sustain a heavy, loose backfill, and the design was made on the basis of supporting the entire weight without counting on the arching effect within the material itself. Only the effective section was used in making the calculations, no allowance being made for any assistance from the waterproofing course of brick nor from concrete covering same.

"The plans of the tunnel provide for an 8-in. waterproofing course outside the tunnel structure, covered by 8 in. of concrete, and extending from the track level and up over the arch."

In Proceedings of the American Railway Bridge and Building Association, Vol. 18, 1908, is published a report of a committee of that body, on the subject of "Waterproofing of Concrete Covered Steel Floors of Bridges."

The report contains information as to methods used in waterproofing solid-floor street crossings on several railroads. The good adhesion of concrete to steel in trough floors was particularly noted in the case of a bridge junked.

No definite recommendations are contained in the committee's report.

Waterproofing With Coal Tar.

Grand Trunk Railway......................A. R. E. A., Vol. 12, Part 1
New York Central & Hudson River Railroad......................
..................................A. R. E. A., Vol. 12, Part 1
New York Central & Hudson River Railroad......................
....A. R. E. A., Vol. 13

Waterproofing With Tar Paint.

Chicago, Burlington & Quincy Railroad.....A. R. E. A., Vol. 11, Part 2
St. Louis & San Francisco Railroad.................A. R. E. A., Vol. 13

General Remarks on Bituminous Waterproofing.

American Society for Testing Materials, Vol. 10:

Cyril de Wyrall: "The greatest disintegrators of asphaltum and pitch bitumens, which are mainly used for waterproofing, are benzole or gas drip, kerosene or petroleum and other like oils, and ferrous hydroxite; the latter substance is a seepage which is common to the gneiss rock formation such as is found on Manhattan Island. These well-known foes of bitumens should be particularly guarded against.

"Hot brick and asphalt were also used in several places (New York Subway), all of which have failed in places where it was most necessary that this should not have occurred.

"Where water has not touched the waterproofing, it has as a rule, held good, but where water has come into actual contact with waterproofing, it has failed. Where the water has been impregnated with benzole or gas drip, due to leaking gas mains, it has gone through the protecting coat of concrete and, in numerous instances, it has so dissolved the bitumen as to cause it to run through the shrinkage cracks between the concrete and the steel, and to drip through on the platforms and tracks. When an excavation was made to repair the waterproofing at some of these points, there was practically nothing left; everything had been dissolved. In short, the waterproofing generally has proved efficient, provided the water has been kept away from it.

"To get an efficient waterproofing material, the chemical tests should be radically changed. A carbon test by heating should be required, and a bitumen should be used, of which at least 30 per cent. should be insoluble in cold naphtha. The running and melting points are much too low. It is folly to specify a bitumen that will run at 60 degrees and melt at 100 degrees Fahrenheit, as it would be impossible to keep it on a vertical wall at a summer temperature, such as is obtained in this latitude, unless it were nailed on, especially with four or five-ply work. A far better specification would be that bitumen should have a melting point of not less than 200 degrees Fahrenheit, and that it should be pliable at 20 degrees Fahrenheit.

"The plan of waterproofing the sides to the ground water level is inefficient as most of the trouble occurs in the roof. Such leaks, together with the gas and the oil from the street railway switches, are a source of considerable expense."

"Five bituminous waterproofing materials used in test conducted by the American Society for Testing Materials, when subjected to the action of Astoria gas drip seepage water from the sump of the New York Subway at 42d Street, same with the addition of 5 per cent. of kerosene and city water to which had been added about 23 per cent. of potash, showed that the bituminous material in every case was partly dissolved and carried away by the gas drip; showed no effect from seepage water, and were somewhat affected by seepage water and kerosene."

SOAP AND ALUM WASHES.

Chicago & Northwestern Railway, American Railway Engineering Association Proceedings, Vol. 12, Part 1.

El Paso & Southwestern System, American Railway Engineering Association Proceedings, Vols. 11, 12, 13.

See Treatise on Masonry Construction, I. O. Baker, for description of and formula for soap and alum method.

MISCELLANEOUS COATINGS.

Technologic Paper 3: "The analysis of compound No. 25 showed 85 per cent. iron and 3½ per cent. sal ammoniac. The material is applied on the surface in a water paste form, hence it can only be a surface filler and does not penetrate. There may be a reaction between the concrete and the material, but the one reaction upon which the value of the compound depends, is the corrosion of the iron by the sal ammoniac in the presence of water. If the resulting corroded iron will adhere to the concrete, the material should have considerable value as a waterproofing material."

National Association of Cement Users, December, 1912, C. M. Chapman:

TESTING MATERIALS FOR WATERPROOFING CONCRETE.

"In practically all the numerous tests of waterproofing made in the past 7 or 8 years, in the laboratory of Westinghouse, Church, Kerr & Co., it has been the custom to expose the test pieces to the action of the weather on the roof of their office building after first testing them and then testing again after 6 or 12 months' exposure. The results of these tests after prolonged exposure show that few, if any, of the materials which are applied to the surface of concrete to waterproof it after it is made, will retain even a small proportion of their efficiency."

CEMENT MORTAR.

Reports on the use of plaster coatings for waterproofing are published in American Railway Engineering Association Proceedings as follows:

Pennsylvania Lines West	Vol. 11, Part 2
Canadian Pacific Railway	Vol. 13
Long Island Railroad	Vol. 13
New York Central & Hudson River Railroad	Vol. 13

(III) INTEGRAL METHODS OF WATERPROOFING.

INERT FILLERS.

In the discussion of inert fillers in the Bureau of Standards Technologic Paper No. 3, the author states that some of the fillers ordinarily used—hydrated lime, feldspar, sand and clay—may be partly changed in time when in the concrete. The hydrated lime may be partly carbonated, especially on the surface; the feldspar may decompose by the leaching out of the alkalies; the sand will change but very little; the clays will be very inert, although some theories have been brought forward which assume a very important role for clay when mixed into concrete.

Under the theory proposed by R. H. Gaines, of the New York Board of Water Supply,* the electricity charged ions of water not only materially aid the chemical combinations of the elements in the cement, but also tend to form a glue-like film around the particles, joining them together and forming a dense and hard mass. By the substitution of a dilute solution of some electrolyte for the water, the more numerous ions of the electrolyte will cause the same binding action to a higher degree, and the resulting product will be more closely bound together, that is, more dense and, therefore, stronger and more impervious. Also by the introduction into the mass of certain substances known as colloids, which have the power of aiding the electrolytic action and at the same time of retarding the too rapid hydration of the calcium ingredients of the cement, the setting process can be carried to a higher degree of density and solidity.

In the experiments reported by Mr. Gaines, 2½ per cent. of alum increased the compressive strength of 1:13 Atlas cement and Cow Bay sand mortar specimens by about 35 per cent. at 90 days; and the tensile strength by about 7 per cent. The permeability tests on the treated mortars showed a great increase in impermeability with the addition of the alum solution.

Similar tests using 5 per cent. of alum showed an increase of about 11 per cent. in the compressive strength at 90 days, and an increase of about 9 per cent. in the tensile strength at 90 days. Permeability tests showed a still greater increase in impermeability. Similar tests in which colloidal clay was substituted for 5 per cent. and 10 per cent. of the sand, showed still greater increases in strengths and in impermeability. A third set of experiments in which colloidal clay was substituted for 5 per cent. and 10 per cent. of the sand used and 2½ per cent. and 5 per cent. of alum solution was used in the mixing water, showed similarly favorable influences on strengths and impermeability.

As a result of the investigations carried on by the commissioners of sewerage at Louisville, Ky., 1910, concrete to be used in wet localities has been made by the substitution for 10 per cent. of the regular (Ohio River) sand, a like amount of fine sand containing some clay, and uniformly satisfactory results have been obtained.

Tests to determine the effect of the waterproofing materials upon the tensile strength of heat and 1:3 mortar briquettes were made in connec-

*See Engineering News, September 26, 1907.

tion with impermeability tests. The mortar briquettes showing the greatest strength at 28 days were those in which 5 per cent. and 10 per cent. of hydrated lime was added and those in which 10 per cent. of molding sand was substituted for an equal amount of sand. Five per cent. of clay and 5 per cent. of molding sand substituted for an equal amount of sand and 5 per cent. of Ceresit added to the mixing water, gave strengths about 75 per cent. of the former. Other tests, with 2½ per cent. and 7½ per cent. of clay in place of sand, gave strengths equal to 65 per cent. of the first mentioned mixtures. McCormick waterproofed cement gave still less strength, two different samples varying nearly 50 per cent.

American Society for Testing Materials, Vol. 8, 1908:

Permeability tests of concrete with the addition of hydrated lime, by Sanford E. Thompson, Lehigh cement, crushed conglomerate rock, which resembles trap in its characteristics and tests, and good, coarse sand, Pine Cone brand hydrated lime.

CONCLUSIONS.

(1) Hydrated lime increases the watertightness of concrete.

(2) Effective proportions of hydrated lime for watertight concrete are as follows:

For 1 cement 2 sand 4 stone, add 8 per cent. hydrated lime.
For 1 cement 2½ sand 4½ stone, add 12 per cent. hydrated lime.
For 1 cement 3 sand 5 stone, add 16 per cent. hydrated lime.

These percentages are based on the weight of dry hydrated lime to the weight of the dry Portland cement.

(3) The cost of large waterproof concrete structures frequently may be reduced by employing leaner proportions of concrete with hydrated lime admixtures, and small structures, such as tanks, may be made more watertight.

(4) Lime paste made from a given weight of hydrated lime occupies about 2¼ times the bulk of paste made from the same weight of Portland cement and is, therefore, very efficient in void filling. Sands containing considerable fine material produce a more watertight, although a weaker concrete. Pressure used, 60 lbs. per sq. in., specimens 8 in. thick. (No strength tests given.)

The author refers to tests made in 1906 in connection with the construction of a reservoir 100 ft. in diameter, 43 ft. high, at Waltham, Mass. Five per cent. of hydrated lime was adopted to mix with the 1:2:4 concrete in building the walls. Results were satisfactory, the only seepage occurring at some of the joints between different days' work, where the bond between the old and new concrete was not made with sufficient care.

In the tests described in Technologic Paper No. 3, hydrated lime was incorporated into a 1:4 mortar with Maramec River sand. The effect of the lime on the compressive strength was to decrease it by about 15 per cent. with the addition of 2 per cent. of the hydrated lime, and to increase it about 2 per cent. with the addition of 10 per cent. of hydrated lime. The effect on the tensile strength was to decrease it by about 20

per cent. in the first case and by about 25 per cent. in the second case.

All the fillers tested were quite effective in increasing impermeability, but the clays appeared to be slightly more effective than the sand or feldspar.

American Society for Testing Materials, Vol. 8, Hydrated Lime and Cement Mortars. E. W. Lazell:

"Hydrated lime is lime slaked with sufficient water so that each particle of quick lime or calcium oxide receives enough water to form the hydrate. It is chemically the same material as lime paste without the excess water to make it wet and plastic. To render the hydrated lime plastic, it is only necessary to add this excess water in the same way as it is added to cement. The hydrate is prepared in a regular plant designed for the purpose and a much more uniform product is produced than by the customary way of slaking lime on the work. The mechanically-treated hydrated lime is further aged in bins or silos like cement before it is placed on the market. Air-slaked lime is radically different in its composition and characteristics from hydrated lime. Air-slaked lime has become slaked by contact with the moisture and carbon dioxide of the atmosphere; it is not of a uniform composition and generally contains considerable free or unslaked lime. On the other hand, hydrated lime is a homogeneous, uniform product, perfectly hydrated. The product goes into the market as a dry powder in bags, and can be as easily handled as cement; therefore, for the preparation of mortar or lime cement mortar, it offers the great advantage of ease of handling and uniformity.

"The tensile strength of 1:3 mortars was in general decreased by the substitution of from 5 per cent. upwards of hydrated lime for an equal amount of the cement in tests extending over a period of 12 months. The tensile strength of 1:5 mortars was in general improved by the substitution of from 10 per cent. to 40 per cent. hydrated lime for an equal portion of cement. Standard Ottawa sand used. Five per cent. substitution decreased strength in both cases.

"It should, therefore, be possible to use in mortars for brick work, an amount of hydrated lime equal to 25 per cent. of the cement used, obtaining thereby a plastic mortar which is much stronger than lime mortar and gains its strength much more quickly. In cement mortar, the addition does not materially decrease the strength and it does, to a marked degree, increase the plasticity. The mortar would, therefore, be easier to place, and laying the bricks would be much facilitated. Plasticity of the mortar would also enable the bricklayer to do better work. Permeability tests on 1:3 mortars, with standard sand, showed some flow in plain cement mortar at 7 days, zero flow at 28 days; specimens 1 in. thick. Subjected to a pressure of 30 lbs. per sq. in. for 1 hour. Impermeable mortars were obtained proportioned 1:5 with 15 per cent. hydrated lime substituted for an equal portion of the cement."

Engineering News, November 7, 1912:

Impermeability tests on concrete made by James L. Davis, when in charge of the laboratory of the New York City Board of Water Supply,

in connection with a design of the Catskill aqueduct, afford an excellent means of judging of the advisability of using inert materials to obtain impermeable concrete.

The following conclusions are drawn in regard to the use of hydrated lime: (1) Hydrated lime is effective in producing impervious concrete, but its use is doubtful economy, except, possibly, for resisting low pressure of water. Concrete in proportions 1:3:6 requires the addition of a proportion of lime equal to about 20 per cent. of the weight of the cement for efficiency against high pressure. This results in a slight loss in the compressive strength of the concrete as compared with the plain 1:3:6 mixture. (2) It is probable it is not an economical material for structures subjected to tensile stress such as reinforced conduits. (3) Except, possibly, for low pressures, equally good results in impermeability can be obtained by the same cost invested in additional cement with resulting stronger concrete. (4) The addition of lime increases the plasticity and mold filling properties of concrete, resulting in smoother surfaces against forms. Its use may give practical advantages in filling around reinforcing steel and other restricted spaces. The maximum density obtained in these tests was .857 on plain, 1:3:6 concrete with straight Portland cement.

Quoted prices in New York per ton: Sand, $1.08; gravel, $1.40; Portland cement, $6.78; high calcium hydrated lime, $8.00; magnesian hydrated lime, $9.50. In commenting on the tests, the author states that both permeability and strength tests are greatly affected by slight excesses or deficiencies in the amount of mixing water used. Under 40 lbs. per sq. in. water pressure, Portland cement concrete in proportions 1.2:3:6 (equivalent to 1:2½:5), or richer, and all proportions of hydrated lime used (0.1 to 0.3 of amount of cement added) give impervious concrete. At 80 lbs. pressure, several of the above described mixes are practically impervious and none of them give much leakage.

High calcium lime is the only material giving entirely consistent results in decreasing permeability in proportion to the amount used.

Similar tests were also made on puzzolan cement. Puzzolan cement is slightly less efficient than the cement hydrated lime construction.

Averaging all comparable proportions, the relative strengths at 3 months age are as follows: Portland cement 100 per cent., calcium lime 85 per cent., magnesian lime 76 per cent., puzzolan cement 81 per cent. Compressive tests on 1:3:6 concrete cylinders 6 in. diameter, 12 in. length. Aggregates used were ordinary quartz sand, and gravel, supplied from Long Island banks for the New York market, sand all passed a sieve with 0.2-in. square openings; the gravel passed a 1¾-in. and was retained on a 0.2-in. sieve.

A record of the volumes of rammed concrete produced in the tests was kept as a check on the volume computed from density tests. The lime does not have an appreciable effect in increasing the volume of concrete, neither does it increase the density, although hydrated lime yields about 2¼ times the volume of paste that an equal weight of Portland ce-

ment does. The density of the richest cement lime paste used was 0.42, the density of plain cement paste was 0.52. The cement lime paste had an excess of volume of paste of 29 per cent. over plain cement paste. With cement lime paste, the maximum density any paste-filled cavity can have is 0.42; with cement paste it may be 0.52.

Based on prices in New York markets, plain Portland cement concrete costs slightly less per cubic yard for materials than any of the other mixes containing equal proportions of cementing materials. For equal efficiency in waterproofing at 40 lbs. pressure, the use of hydrated lime reduces the cost of materials about 5 cents per cu. yd. of concrete (equal to 1⅓ per cent.).

Tests similar to those on hydrated lime were made with a white, pure clay from Georgia, intended to represent high-grade material in colloidal properties. Plain concrete of two percentages of cement, 10 per cent. and 11 per cent., were selected as the basis of the tests, the total percentages of fine material in the dry mix, 45 per cent., remaining constant. A group of specimens was made up in which 5 per cent., 7½ per cent. and 10 per cent. of clay was substituted for an equal amount of sand. A second group was made up in which equal percentages of extra cement were substituted for similar percentages of sand. The clay used passed a No. 30 sieve. The author's conclusions in regard to the use of clay are as follows: (1) clay added to ordinary concrete gives beneficial results in permeability and strength with no practical effect in density; (2) compared with an equal excess of cement by weight, clay gives no advantage of practical importance in permeability or density, and results in a loss of strength; (3) both processes give impermeable concrete under 80 lbs. pressure; (4) if the use of clay is practicable on a working scale, its possible economic use under two methods is evident: (a) By mixing with the cement at the cement mill. The mixed material would have to be sold about 20 per cent. cheaper than ordinary cement. (b) By mixing in the field in localities where the cost of cement is high and clay can be obtained very cheaply.

The maximum density obtained in this series of tests was 0.807 in a specimen containing 12 per cent. of cement.

It is noted that concrete of ordinary sand and gravel containing 13.5 per cent. (approximately equivalent to 1:2½:5 mix) of cement was impervious at a pressure corresponding to 185 ft. head of water. It is noticeable that the clay gives better results in the leaner concrete. This seems to indicate that the clay acts simply in a manner similar to very fine aggregate, for it is well known that lean concretes are benefited in strength by the addition of fine material, such as loam and dust, which rich concretes are not.

Special appliances for handling clay would be necessary. The clay used in these tests when pulverized to pass a No. 30 sieve, 54 per cent. passed the No. 100 and 15 per cent., the No. 200 sieve. Should it be found necessary to adopt the method used in practice, the process would involve considerable expense. The less expensive method, if found practicable would be to add the clay to the mixing water.

Tests in which blue New York brick clay was substituted for the white Georgia clay gave similar results.

Tests have demonstrated that finely divided material as hydrated lime, clay, puzzolan cement, sand cement and very fine sand may be used to produce highly impermeable concrete. The same result can, however, be obtained by the use of an extra amount of Portland cement at less cost, usually, than by any of the special materials, and in all cases with an increase in the strength of the concrete over the other materials. For impermeable construction, concrete should contain not less than 45 per cent. of combined fine aggregate and cement, with ordinary aggregates; 15 per cent. to 18 per cent. of the entire dry mixture should be cement, unless the resisting walls are several feet in thickness.

Observations showed that fairly uniform rates of leakage would be established within 30 minutes after pressure was applied. Tests in which a range of pressure up to 100 lbs. per sq. in. was used, indicated that leakage increases more rapidly than pressure. It is probable that under continued action, the rate of leakage would decrease in the usual manner.

Experiments were made by the Ulster & Delaware Railroad Company to determine the effect on strength and impermeability of mortar of the addition of clay and colloids.

Results of 90-day breaks are as follows: The addition of 5 per cent. of alum reduced the tensile strength of 1:3 mortar briquettes in which clay had been substituted for 12½ per cent. and 22½ per cent. of the cement used by about 10 per cent. to 15 per cent. The addition of 2½ per cent. of alum reduced the tensile strength of similar mortars from 1 per cent. to 9 per cent. The addition of 2½ per cent. of alum decreased the strength of 1:3 cement mortar briquettes 9 per cent., and the addition of 5 per cent. of alum increased the strength 2½ per cent.

In these experiments the substitution of 12½ per cent. of clay for an equal amount of the cement increased the tensile strength of 1:3 mortar briquettes by 7 per cent. with two kinds of clay, and decreased the tensile strength an equal amount with another kind of clay. The substitution of 22 per cent. of clay reduced the strength from 2 per cent. to 15 per cent.

In a discussion of the adulteration of Portland cement, by R. C. Carpenter, Professor of Experimental Engineering, Cornell University, in reference to the claim that by the use of certain adulterants in Portland cement quality could be improved rather than otherwise, he states that so far as investigations have been made in the past, there is a good deal to support such a statement. The following inert materials have been ground into the Portland cement materials subsequent to calcination: (a) clay (either raw or burned); (b) slaked lime; (c) sand; (d) ashes; (e) natural cement; (f) pulverized natural rock, like rag-stone or tufa.

His investigations indicated that Rosendale cement could be ground with Portland cement in practically equal quantities, with no loss in sand-carrying quality or strength.

Good results obtained with silica cement, made by grinding over fine sand into Portland cement, were thought by many engineers to come largely

from the extra grinding which the Portland cement received when the sand was added. The expense of this product forbids its use. Some engineers report decrease of long-time strength with silica cement when mixed with sand, although showing better results than straight Portland neat. It is quite evident that any inert material to be of value must not lessen the good qualities of the cement when used with normal amounts of sand.

Regarding the use of tufa cement on the Los Angeles aqueduct up to the present time, investigations have not indicated that the practice was dangerous, or that the resulting structures would be weak and would not be permanent. Sufficient time has not elapsed to make it safe to draw any other conclusions.

Slaked lime added to cement after calcination has a decided effect in regulating the setting and also tends to make the mortar waterproof. Slaked lime must be used with care, since any particles which are not thoroughly hydrated tend to make the cement unsound. It is rather expensive and is not likely to be largely used because of the fact.

INTEGRAL COMPOUNDS.

Active Fillers.—Some compounds are supposed to react with certain of the constituents of the cement to form other compounds which will be inert and fill the voids. Resinate of potash in the presence of the free lime of the concrete would react to form the more insoluble resinate of lime. Certain saponifiable oils will form an insoluble lime soap with the concrete. These lime soaps are not only almost insoluble in water, but they are also not wet by it, consequently they form the basis of the water-repelling compounds. However, in themselves, these materials are not waterproof, but become so only as a result of a series of reactions, and it would be better to use the result of these reactions directly and not depend upon something that may not always take place.

From Technologic Paper No. 3: The following is a summary of conclusions presented in Bulletin No. 46, Office of Public Roads, United States Department of Agriculture:

"The following conclusions as to the effect of the oils used in cement and concrete may be drawn from the foregoing investigations:

"(1) The tensile strength of 1:3 oil-mixed mortar is very little different from that of plain mortar, and shows a substantial gain in strength at 28 days and 6 months over that at 7 days.

"(2) The times of initial and final set are delayed by the addition of oil; 5 per cent. of oil increases the time of initial set by 50 per cent., and the time of final set by 47 per cent.

"(3) The crushing strength of mortar and concrete is decreased by the addition of oil to the mix. Concrete with 10 per cent. of oil has 75 per cent. of the strength of plain concrete at 28 days. At the age of 1 year the crushing strength of 1:3 mortar suffers but little with the addition of oil in amounts up to 10 per cent.

"(4) The toughness or resistance to impact is but slightly affected by the addition of oil in amounts up to about 10 per cent.

"(5) The stiffness of oil-mixed concrete appears to be but little different from that of plain concrete.

"(6) Elasticity.—Results of tests for permanent deformation indicate that no definite law is followed by oil-mixed concrete.

"(7) Absorption.—Oil-mixed mortar and concrete containing 10 per cent. of oil have very little absorption, and under low pressures both are waterproof.

"(8) Permeability.—Oil-mixed mortar containing 10 per cent. of oil is absolutely watertight under pressures as high as 40 lbs. per sq. in. Tests indicate that oil-mixed mortar is effective as a waterproofing agent under low pressures when plastered on either side of porous concrete.

"(9) The bond tests show the inadvisability of using plain bar reinforcement with oil-concrete mixtures. The bond of deformed bars is not seriously weakened by the addition of oil in amounts up to 10 per cent."

Tests conducted by the Institute of Industrial Research on oil-mixed mortars have given good results. Fifteen per cent. (of cement weight) of oil incorporated in 1:3 cement, standard sand and mortar briquettes, showed no decrease in tensile strength at 6 months, as compared with water-mixed briquettes and showed an absorption of only 2 per cent., as compared with 6.8 per cent. for the latter. The addition of clay to the oil in amount equal to 7 per cent. of the weight of oil used, did not decrease the absorption. The results at the end of one year show practically the same strength for the oil-mixed briquettes as the straight water-mixed briquettes and absorption of 3.6 per cent., as compared with 6.9 per cent. for the latter. The addition of clay in amount equal to 7 per cent. of the weight of the oil used, gave practically the same results as the oil alone. The addition of whiting to the oil in similar amount decreased the strength considerably.

In a discussion of alternative designs for a dam in Engineering News, Vol. 68, No. 10, Edward Wegmann, Consulting Engineer, Department of Water Supply, Gas and Electricity, New York City, gives the results of some tests of waterproofing compounds:

"Mixtures of each compound were made with 1 part cement and 2 parts of clean, quartz sand. The samples to be tested were left one day in air and 34 days in water.

Trade Name.	Manufacturer.	Per Cent. Used.	Strength in Lbs. Per Sq. In. Tension.	Compression.
1:2 Cement and Sand, (no waterproofing)			490	4,655
Shamrock	McCormick Waterproofing Portland Cement Co......	3	469	4,136
Medusa	Sandusky Portland Cement Co.	4	417	3,889
Metal-Crete	Klein Mfg. Co.............	5	454	5,055
Marvel	Goldstein Waterproofing Products Co.	1	466	3,412
Crude Oil	....	10	362	4,509
Integrol	Wemlinger Steel Piling Co.	One in 25 pts. of water.	391	....

"While the tests made were not numerous enough, nor continued sufficiently long to give conclusive results, they show that the admixture of any of the compounds with the cement always diminished somewhat the tensile strength of the mortar. Tests made recently for the Department of Water Supply, Gas and Electricity of the city of New York gave similar results. This diminution of tensile strength may be less appreciable in tests for longer periods.

"In the tests for watertightness of mortar mixed with the waterproofing compounds, blocks were subjected to a water pressure of 75 lbs. per sq. in. None of the cubes showed loss of water through the mass when subjected to the water pressure, and they all appeared to be practically watertight.

"The engineers in charge took under consideration the fact that the Ambursen Hydraulic Construction Company has made the decks of many dams it has built practically watertight by using a wet mixture of 1:2:4 concrete. In view of the reduction in tensile strength of mortar containing a waterproofing compound, indicated by the tests, it was finally decided by the engineers not to use any integral waterproofing."

WATER-REPELLING COMPOUNDS.

(Information from Technologic Paper No. 3.)

These are stearates of lime or soda and potash. Stearate of lime (lime soap) is almost insoluble in water and is also not wet by it.

The stearates of soda and potash are ordinary soap readily wet and soluble in water. With these there is a reaction when they are treated with water in the presence of the cement; the soda or potash soap is dissolved and precipitates the more insoluble lime soaps, the result being the same compound as the rest of this class contains.

The claim made by the manufacturers that these compounds are water repellent is inconsistent in that they must be thoroughly surrounded by water when mixed with the aggregate, if the normal strength of the concrete is to be developed. When so mixed in the concrete, their water-repellent action would be lost. If it repels the water from the concrete, it must necessarily repel it from the cement and prevent the latter from attaining its usual strength.

Several manufacturers have added water-repelling materials directly to cement and offer it to the public as waterproofed cement. This repelling material is similar to that used in the water-repelling compounds, consequently, the remarks made under that class apply here.

ALUM AND SOAP.

The alum is mixed with the cement in the form of a fine powder, and the soap is dissolved in the water used in mixing concrete, or both the alum and the soap may be dissolved in the water. The effect of the addition of these materials is generally to increase the impermeability and decrease strength.

Lime and soap are incorporated into the concrete mixture as waterproofing ingredients. Their action is the same as that of alum and soap.

An analysis of waterproofed cements (Technologic Paper No. 3) showed in one case an addition of fine sand, in another a very small amount of potash soap.

National Association of Cement Users, December, 1912, C. N. Chapman:

In the case of those methods by means of which the entire mass of the concrete is designed to be waterproof, there is shown sometimes a steady improvement after exposure and sometimes a marked decline. In some cases the life of the waterproofing is very short and the failure after a few months' exposure almost complete.

It is important therefore, before any particular method of waterproofing be adopted, that the probable life of the treatment be ascertained. It is pretty well established that a good concrete without foreign substance in it, improves with age and becomes more dense and watertight, but the same cannot be said as positively of a concrete containing some of the recently developed compounds intended for waterproofing.

The use of integral compounds has been reported in A. R. E. A. Proceedings as follows:

Nashville, Chattanooga & St. Louis Railway..........Vol. 11, Part 2
Oregon-Washington Railroad and Navigation Company..........Vol. 13
Santa Fe ....Vol. 13
Union and Southern Pacific System.............................Vol. 13

The following summary is presented in Technologic Paper No. 3, of the Bureau of Standards, Department of Commerce and Labor:

Portland cement mortar and concrete can be made practically watertight or impermeable (as defined below) to any hydrostatic head up to 40 ft., without the use of any so-called "integral" waterproofing materials; but in order to obtain such impermeable mortar or concrete considerable care should be exercised in selecting good materials as aggregate and proportioning them in such a manner as to obtain a dense mixture. The consistency of the mixture should be wet enough so that it can be puddled, the particles flowing into position without tamping. The mixture should be well spaded against the forms when placed, so as to avoid the formation of pockets on the surface.

The addition of so-called "integral" waterproofing compounds will not compensate for lean mixtures, nor for poor materials, nor for poor workmanship in the fabrication of the concrete. Since in practice the inert integral compounds (acting simply as void filling material) are added in such small quantities, they have very little or no effect on the permeability of the concrete. If the same care be taken in making the concrete impermeable without the addition of waterproofing materials as is ordinarily taken when waterproofing materials are added, an impermeable concrete can be obtained.

The terms "permeability," "absorption" and "damp-proof" should not be confused. A mortar or concrete is impermeable (not necessarily damp-proof), as defined and used throughout this report, when it does not permit the passage or flow of water through its pores or voids. The

absorption of a mortar or concrete is the property of drawing in or engrossing water into its pores or voids by capillary action or otherwise. If the pores or voids between the grains or particles or in the individual grains are sufficiently large and connected from surface to surface of the wall, the concrete will be permeable to water. If the pores or voids are very minute, but connect with another, theoretically they may act as capillary tubes, absorbing or drawing in and filling themselves with water; but the capillary forces will tend to hold the water in the pores and will prevent the passage or flow of water, even though one surface of the wall may be exposed to a considerable hydrostatic pressure. For all practical purposes a wall under such conditions would be considered perfectly watertight and impermeable, although it may be highly absorptive. If these minute pores do act as capillary tubes and are never minute enough to prevent capillary action, the moisture either as water or water vapor would in time penetrate entirely through and fill a concrete wall, no matter what the thickness or composition. In such a case the capillary forces would not permit an actual flow of water, but these forces may carry moisture entirely filling the wall, and unless evaporation is retarded, the opposite face of the wall would appear dry. In such a case, the concrete would be considered impermeable, but not damp-proof.

The damp-proofing tests as conducted would indicate that Portland cement mortars can be made not only impermeable but damp-proof as well, as defined above, without the use of any damp-proofing or waterproofing compound. However, these tests should be interpreted with caution, as the evaporation may have been sufficient to care for the slight amount of moisture coming through the test pieces without indicating on the filter paper. Thus it cannot be stated that if a material were used which was damp-proof according to this test, if used as a basement wall, one surface being constantly exposed to moisture and the other surface in an inclosed room where there would be little or no circulation of air, that the interior surface would not appear damp and the atmosphere become saturated with moisture. The tests of coating materials as damp-proofing mediums can be considered as only preliminary, but the results considered along with the chemical discussion, throw some light on their comparative merits. The mortar used in these tests was, perhaps, too coarse and too absorptive for a fair test. The purpose of the rough surface was to test the flowing qualities of the coating, and it would seem that many of the failures may be due to the poor or imperfect spreading and adhesive quality. Several of the compounds deteriorated and proved their unfitness for the purpose intended.

Well-graded sands containing considerable graded fine materials are preferable for making impermeable concrete, but if such is not to be had, fine material in the form of hydrated lime, finely ground clay, or an additional quantity of cement will be found of value.

Where Portland cement mortar is used as a plaster coat, if sufficient cement be used and the sand contains sufficient fine material (or a fine

material be added) and the mortar be placed without joints, and well troweled (care being taken not to over-trowel which may cause crazing), the coating will be effective as an impermeable medium without the use of any waterproofing compound.

As a precaution under certain conditions, it is undoubtedly desirable to use bituminous or similar coatings, even on new work, as protection where cracks may occur, due to settling of foundation or expansion and contraction caused by temperature changes. In large or exposed work it is practically impossible to prevent some cracks, but where cracks can be prevented, no coating whatever is required to make the structure impermeable.

The permeability of Portland cement mortars and concretes rapidly decrease with age.

None of the integral compounds tested materially reduced the absorption of the mortars before they were dried by heating at 212 degrees Fahrenheit. Thus they would have little or no practical value. But some of the so-called integral waterproofing compounds did decrease the absorption after drying the mortars at 212 degrees Fahreanheit, and the rate of absorption was much slower in these cases. The addition of hydrated lime and clays seemed to have little or no effect on the absorption.

The addition of any of the compounds tested to a mortar in the quantities as used in these tests does not seriously affect the compressive or tensile strength. The addition of the inert void fillers to mortars, as used in these tests, up to 20 per cent. of the volume of cement increases the compressive strength.

Tests of waterproofing materials (Technologic Paper No. 3) comprise the results of experiments made to determine the permeability of 1:4, 1:6 and 1:8 mortars of "quaky" consistency made with typical Portland cement and Meramec river sand. It was found that any mortar richer in cement than a 1:4 proportion was impervious in itself under a hydrostatic pressure of 20 lbs. to the sq. in.

(IV) WATERTIGHT CONCRETE.

Reports published in Proceedings A. R. E. A. concerning the use of concrete without waterproofing in locations where impermeability is required are as follows:

T. L. Condron	Vol. 11, Part 2, Vol. 13
Chas. M. Mills	Vol. 11, Part 2
Indianapolis Water Co.	Vol. 13
El Paso & Southwestern System	Vol. 13
Chicago, Milwaukee & St. Paul Railway	Vol. 11
Southern Pacific Company	Vol. 11
Union Pacific Railroad	Vol. 12

In Engineering News, December 14, 1911, C. Raymond Hulsart describes the construction and testing of a concrete tunnel lining: "A recent test in the Wallkill Pressure Tunnel of the Catskill Aqueduct on the

new water supply for New York City showed the practicability of making the concrete construction watertight against high heads. The test was made upon the concrete lining of the tunnel which is being constructed of a nominal 1:2:4 concrete without the use of any waterproofing material, and in rock excavation."

"Tested up to 135 lbs. per sq. in. hydrostatic pressure applied to the outside of the concrete tunnel lining through grout pipes which were inserted through the lining during construction.

"The author states it may be safely concluded . . . . that with reasonable care in mixing and placing of concrete and with sufficient excess cement, a concrete can be had which will be practically watertight against hydrostatic heads of several hundred feet. In case of tunnel lining, proper care in placing of course includes care in arrangement of collecting pans and weepers to carry leaking ground water through the concrete and forms without damage to the body or finish of the concrete.

"The large aggregate used in the concrete was crushed Bonticou grit, a metamorphosed gravel containing 43 per cent. voids. It was a well graded aggregate ranging from ¼ up to 1¾ in. in size. A very clean, rather fine bank sand was mixed with Bonticou grit screenings in proportions of 2 parts of sand to 1 part of screenings. This gave a well graded sand containing 38 per cent. voids.

"In the concrete, 1.7 barrels of cement was used per cubic yard of concrete, and 7.1 per cent. of water by weight of dry materials, giving a wet mix."

WATERPROOFING.

(Progress Report Joint Committee, A. R. E. A., Vol. 11, page 1004.)

"Many expedients have been used to render concrete impervious to water under normal conditions, and also under pressure conditions that exist in reservoirs, dams and conduits of various kinds. Experience shows, however, that where mortar or concrete is proportioned to obtain the greatest practicable density and is mixed to a rather wet consistency, the resulting mortar or concrete is impervious under ordinary conditions. A concrete of dry consistency is more or less pervious to water, and compounds of various kinds have been mixed with the concrete or applied as a wash to the surface for the purpose of making it watertight. Many of these compounds are of but temporary value, and in time lose their power of imparting impermeability to the concrete.

"In the case of subways, long retaining walls and reservoirs, leakage cracks may be prevented by horizontal and vertical reinforcement, properly proportioned and located, provided the concrete itself is impervious.

"Such reinforcement distributes the stretch due to construction or settlement, so that the cracks are too minute to permit leakage, or are soon closed by infiltration of silt. Asphaltic or coal tar preparation, applied either as a mastic or as a coating on felt or cloth fabric, is used for waterproofing, and should be proof against injury by liquids or gases."

REINFORCING FOR SHRINKAGE AND TEMPERATURE STRESSES.

(Progress Report Joint Committee, A. R. E. A., Vol. 12, page 479.)

"Where large areas of concrete are exposed to atmospheric conditions, the changes of form, due to shrinkage (resulting from hardening) and to action of temperature, are such that large cracks will occur in the mass, unless precautions are taken to so distribute the stresses as either to prevent the cracks altogether, or to render them very small. The size of the cracks will be directly proportional to the diameter of the reinforcing bars and inversely proportional to the percentage of reinforcement and also to its bond resistance per unit of surface area. To be most effective, therefore, reinforcement should be placed near the exposed surface and well distributed, and a form of reinforcement used which will develop a high bond resistance."

American Society for Testing Materials, Vol 8, Committee "S":

"Sub-Committee 'A' has carried on an extensive series of tests both of materials incorporated with cement at the time of manufacture or added thereto or to the gage water at the time of use and of those materials used simply as protective coatings. The tests undertaken comprise the making of briquettes from cement mortars in the several proportions of 2:1, 3:1 and 4:1 of both a fair natural sand and standard quartz or Ottawa sand with both treated and untreated material to obtain comparative results concerning tensile strength at different periods. Discs of identically the same material were similarily made up to determine the comparative effect on permeability of the treatment with the various waterproofing compounds. It has thus far been demonstrated pretty conclusively that as was generally known, with the care and facilities of laboratory work, untreated mortar of a fair natural sand, even as lean as 4:1, can be made practically waterproof. Similar mortars of standard quartz or Ottawa sand fail to show corresponding impermeability when untreated, but when treated with several waterproofing materials, showed considerable improvement in this feature, which, it can be concluded, was due to mechanical improvement of the mortars by an increase in their granulometric value through the filling of the voids with the dry, or in case the compound is added as a liquid, suspended matter, rather than through any chemical action. From the action of most of the materials experimented with, it may be concluded that in a poorly proportioned mortar or concrete and under the more unideal conditions in the field where immediate results are wanted, many of the compounds do materially decrease the permeability of aggregates for the time being, but so far, no claim for permanent action on their part is warranted. This condition arises in time, with any well proportioned and properly laid concrete through the mechanical filling of the voids by percolation of water carrying natural deposits. A condition of marked impermeability was, however, very generally obtained with no impairment of strength by the substitution of small percentages of very finely comminuted clay for sand, even when this was standard Ottawa sand. This was without the use of an electrolyte which has been claimed to be

helpful although this was not confirmed by our experiments. No beneficial effect on tensile strength was noticed from the use of any of the so-called waterproofing materials; in fact, indications only to be corroborated from much longer time tests point rather to the impairment of strength, a weakening of the mortars, even though greater impermeability may be obtained."

American Society for Testing Materials, Vol. 9, Report of Committee "S":

"The results of the present year's tests corroborate very generally the conclusion previously noted with the additional positive information that with even such ungraded materials as crushed quartz or standard Ottawa sand, no difficulty is experienced in a carefully conducted laboratory in obtaining waterproof mortars in such lean proportions as 1 part cement to 4 of sand. There is no excuse for failure when a fairly graded natural sand is used with even leaner mixtures, confirming the fact that the necessity of waterproofing treatment with ordinary field concrete mixtures, is due either to the use of poor materials or to poor proportioning or bad handling or to all of these combined.

"We think it has been demonstrated and will be generally admitted that with proper materials and proper proportioning and handling of the subsequent mixtures, these need no addition of foreign substances to become initially waterproof; that when such addition is needed for reasons stated above, the desired end can be and is most easily secured mechanically through proper void filling, compensating for the poor proportioning, and for poor quality of the original constituents. Any chemical action claimed for mixtures operating toward securing waterproof concrete is apparently *nil*. Since void filling is to be sought as the panacea for waterproofing ordinary field concrete, comparative tests through the addition of percentages of colloidal clay or hydrated lime and the various advertised waterproofing compounds have been carried on continuously with the conclusion at this date that no general results are obtainable from the use of patented or proprietary compounds which cannot be obtained equally well through the addition of colloidal clay or hydrated lime.

"Furthermore, it seems to be very generally proved by corroborative tests, the results of which will be submitted later when including longer time tests, that, as stated in last year's report to be likely, a weakening in tensile strength in time follows the use of many of the patented compounds, which effect is not generally marked when colloidal clay or hydrated lime is used. It has been concluded that the so-called patented compounds fail to remedy defectively proportioned concrete of poor materials as effectively as colloidal clay or hydrated lime, simply because they do not carry sufficient fine material called for by existing conditions. The apparently waterproofing effect of some of these proprietary compounds at early stages, with the very common loss of strength later on, only confirms the opinion as to their temporary effect being entirely mechanical in aiding through deposits to fill voids to the desired end, which can be permanently better assured by the use of proper percentages of fine material such as colloidal clay or hydrated lime."

American Society for Testing Materials, Vol. 10:

"While a large number of tests on as many as 40 or 50 waterproofing compounds have been independently made by several members of the Committee, this number does not include all the materials exploited from time to time, for they are of mushroom growth." . . . . "In the opinion of the Committee, several facts are established: (1) that the general effect of these incorporated foreign compounds is to reduce the tensile strength of mortars. This refers to a general reduction in the strength of mortars carrying these so-called incorporated waterproofing admixtures, when compared with standard untreated mortars; (2) that resistance to water penetration in mortars and concretes being essentially dependent upon the density of the normal ingredients (all other conditions of handling and placing being normal), that no addition of any foreign substance is absolutely necessary; (3) that when through lack of proper volumetric proportioning in the aggregate (sand in mortar or sand and stone in concrete) some extraneous material is needed to insure filling the voids, this can be accomplished by the use of natural materials such as colloidal clays or hydrated limes, and practically perfect results obtained without resorting to the use of proprietary materials whose general effect is to reduce the strength, with no marked improvement, as a rule, in water-resisting characteristics. Investigations to date do not show that the effect of any of the admixtures is other than mechanical." . . . . "It is an admitted fact that theoretically waterproof mortars and concrete can be secured by proper proportioning, proper mixing, and proper handling of their ingredients and this has been repeatedly accomplished in practice under proper organization and supervision without the use of any admixtures of so-called waterproofing materials and can in any case be secured even with poor natural materials by the addition of similar natural material. It appears that the claim of waterproofing characteristics advanced for most of the proprietary materials examined, cannot be substantiated by any laboratory tests so far developed."

Appendix C.

DISINTEGRATION OF CONCRETE AND CORROSION OF REINFORCING METAL.

The subject of the disintegration of concrete, when investigated with the object of preparing a report that shall be of value to engineers, leads directly to the study of the causes of disintegration and the means whereby it may be prevented. The corrosion of reinforcing metal confines investigation to a study of reinforced concrete. Inasmuch as corrosion of reinforcing metal ultimately leads to disruption of the surrounding concrete and ordinarily presupposes disintegration of the concrete, the subjects are closely allied.

Your Committee has endeavored to present in a concise form recognized good practice relating to those particular features of concrete construction which must be observed in order to prevent disintegration of concrete and corrosion of reinforcing metal. It is to be noted that in work where extraordinary provisions are made for peculiar conditions, the requirements of good design and good engineering in general, covering both materials and methods, must be none the less rigidly adhered to.

Failure to provide for shrinkage of concrete due to hardening in air, and for expansion and contraction due to temperature changes, is a common cause of cracks which are sometimes ascribed to disintegration.

The requirements for good materials have been described in numerous tests, specifications and reports, together with the methods of determining whether the materials meet the requirements. However, the proper precautions are not usually observed in selecting concrete aggregates. The use of crushed stone screenings as fine aggregate is a frequent cause of disintegration and resultant corrosion of reinforcement.

To obtain good work, competent and ample supervision is absolutely necessary.

CONCRETE IN SEA WATER.

Investigations concerning the effect of sea water on concrete immersed for periods up to fifty years or more; of the relative merits of standard Portland cement and Portland cement made with different proportions of its principal constituents, in resisting the disintegrating effect of sea water; of the effect of varying the proportions of cement in the mortar and concrete; of differently graded aggregates; of the addition of various finely ground materials to the cement after burning; of the relative durability of concrete cast in place as compared with concrete blocks allowed to harden before placing in the sea; and of the effect of various materials added to the concrete mixture to produce impermeability and consequent increased durability, have been made in European countries and in America.

Regarding the chemical composition of the cement, the following conclusions are presented:

Cement containing up to 2½ per cent. of SO_3 resists the action of sea water fully as well as cement with lower SO_3 content.*

While all the hydraulic cements now in use are liable to decomposition in sea water, Portland cement is the one to be preferred in every respect.†

High iron Portland cement and puzzolan cement have failed to show superiority over standard Portland cement in resisting the disintegrating effect of sea water.‡

Regarding the effect of varying the proportion of cement in the mortar and concrete, in general the richer mixtures have been found to offer better resistance to the attack of sea water. Proportions recommended for mortars are those with one part cement to one part sand up to one part cement to two parts sand. The bad condition of mortar leaner than the above after exposure in sea water stands out prominently.§ In the use of reinforced concrete for maritime works, it is advisable to employ larger proportions of cement than are usual for similar works in fresh water.||

Concerning the addition of finely ground material to the cement after burning, it has been found that the addition of puzzolana to Portland cement increases the resistance of the resulting mortar or concrete to the disintegrating effect of sea water.¶

Regarding the use of any material added to the concrete mixture in small quantities in order to reduce permeability, no results of practical working tests have demonstrated that the effect of any material in reduc-

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*The effect of SO_3 in Portland Cement. Special publication. Proceedings of Association of German Portland Cement Manufacturers, 1911.

International Association for Testing Materials, 1912. Proposal for Establishing a Standard SO_3 Content for Portland Cement. Association of German Portland Cement Manufacturers.

†International Association for Testing Materials Proceedings of the Sixth Congress, Second Section, 1912. "Action of Sea Water on Hydraulic Binding Media." Lombard and Deforge.

International Association for Testing Materials, 1912. "Action of Sea Water on Reinforced Concrete." de Blocq van Kuffeler.

‡See Engineering News, September 7, 1911, editorial, "The Different Iron and Slag Cements;" also Engineering News, August 3, 1911—"Ferrite Cement and Ferre Portland Cement," E. C. Eckel—for definition of cements.

International Association for Testing Materials, 1912. "The State of Preservation of Test Blocks," by W. Czarnowski.

Proceedings National Association Cement Users, 1912—P. H. Bates, Bureau of Standards.

§International Association for Testing Materials, 1912. "Action of Sea Water on Hydraulic Binding Media." Lombard and Deforge.

International Association for Testing Materials, 1909. "Cement in Sea Water." A. Poulson.

||International Association for Testing Materials, 1912. "Action of Sea Water on Reinforced Concrete." de Blocq van Kuffeler.

¶International Association for Testing Materials, 1912. "Action of Sea Water on Reinforced Concrete."

Engineering News, September 7, 1911. "Official German Recognition of the Harmless Nature of a Slag Addition to Portland Cement Clinker."

International Association for Testing Materials, 1909. "Experiments on the Decomposition of Mortars by Sulphate Waters." G. A. Bied.

International Association for Testing Materials, 1909. "Cement in Sea Water." A. Poulson.

ing permeability is other than mechanical, i. e., to supply a deficiency in fine material in a poorly graded concrete mixture.

Allowing the concrete to harden under favorable conditions before exposure to the action of sea water greatly increases its resistance to attack by the sea water and is recommended wherever possible.

When concrete is deposited under sea water, such precaution should be observed as will prevent the washing of the cement from the mixture.*

Forms should be so tight as to prevent the entrance of sea water after depositing the concrete, in order that a smooth dense surface may be obtained.

The combined effect of freezing and of sea water is noted on marine structures in northern latitudes between high and low tide levels. Under these conditions the disintegrating effects are particularly severe.

Dense, properly hardened concrete is not affected by the action of sea water. Where the concrete is porous, however, it is likely to be damaged by frost action, especially between tides. There is no evidence, however, that porous concrete is damaged by sea water in latitudes where there is no frost.

The making of a dense, impermeable concrete by the use of a well-graded aggregate, rich mixture, proper consistency, and good workmanship, and allowing the concrete to harden under favorable conditions before being exposed to the action of sea water, is generally conceded to be an efficient means of satisfactorily insuring the preservation of concrete in maritime works.

CONCRETE SUBJECTED TO THE ACTION OF WATER CONTAINING ALKALIES.

Investigations concerning the effect of ground waters which contain alkalies on concrete have disclosed several instances of apparent disintegration. The following points have been demonstrated in regard to the resistance of concrete to these agencies.

Concrete in which poor aggregates and lean mixtures have been used and in which the material has been carelessly placed, when coming in contact with alkali seepage may be affected thereby.

The aggregates should be composed of materials inert to alkalies present in the water. A chemical examination of the sand from country known to contain alkaline soils is recommended.

Water containing substances known to react with the elements of the cement should be kept from coming in contact with concrete until the latter has thoroughly hardened.

Care should be taken to provide a smooth surface and sufficient slope to the extrados of the arch of tunnel linings when the ground water level lies below the tunnel grade to facilitate the flow of seepage water to the sides. The back filling over the arch should consist of porous

should be used where necessary and connected with an under-drain, which should be provided in all cases.

The alkalies which are most active in causing disintegration of concrete when allowed to penetrate into the interior of the mass, are the sulphates of sodium and magnesium.*

The measures to be used in making concrete which is to be exposed to the action of these deteriorating agencies in order to prevent disintegration are the same as recommended for sea water construction. Impermeability is the prime requisite, and the results of experiments and practical tests indicate that concrete, carefully prepared, is just as resistant, if not more so, than if mixed with foreign materials or special preparations.

MISCELLANEOUS CAUSES OF DISINTEGRATION.

Cinders give unsatisfactory results in concrete, especially if there is much coke or porous material present. Such cinders may be improved if allowed to weather, with occasional washing until the ferrous iron and sulphur have been oxidized and leached out.†

Cinder concrete in roofing slabs exposed to the action of locomotive gases is not an efficient protection for reinforcing metal, which has been found to corrode and cause the disintegration of the slab.‡

Freshly made concrete surfaces in contact with smoke gases at temperatures below 45 degrees Fahrenheit have failed to harden properly, and experiments indicate that under such conditions the cement is acted upon by the gases. It has therefore been recommended that when heating is done by means of open fires, higher temperatures should be maintained.§

EFFECT OF ELECTRIC CURRENTS.

Laboratory experiments furnish most of the information which exists concerning the effect of electric currents on concrete and reinforcing metal. The discrepancy between the conditions in these experiments and field conditions seems to be greater than is the case in other laboratory tests on structural materials, and the information obtained up to this time is difficult of application to field conditions.

It has not been shown that plain concrete is affected by the passage of an electric current through it.‖

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*P. H. Bates, Bureau of Standards, in Proceedings International Association for Testing Materials, 1912.

See also Technologic Paper No. 12, Bureau of Standards, 1913.

†Journal of Industrial and Engineering Chemistry, June. 1912. "Some Observations on the Disintegration of Cinder Concrete," by George Borrowman.

‡Engineering Record, July 30, 1910. "Replacing Concrete Roof Slab. La Salle Street Station."

§American Society for Testing Materials, Vol. 9. Alfred H. White. "Disintegration of Fresh Cement Floor Surfaces."

‖See Journal of American Concrete Institute, Vol. 1, No. 1, November, 1913. Published at its office, Harrison Building, Philadelphia, Pa. "Effects of Electric Currents on Concrete," by E. B. Rosa, Burton McCollum and D. S. Peters, of the Bureau of Standards, Washington, D. C.

CORROSION OF REINFORCING METAL.

Tests and experience have proved that steel embedded in dense concrete will not corrode, when located either above or below fresh or sea water level. Concrete, in order to be an efficient protection to steel must be rich in cement and mixed to such a consistency as to flow around and completely coat the reinforcing metal.

Steel to be embedded in concrete should not be painted.

CONCLUSIONS.

(1) Concrete exposed to the action of sea water, or in contact with alkali waters, or exposed to gases containing sulphur, or in which reinforcing metal is embedded, should be dense, rich in Portland cement and allowed to harden under favorable conditions before exposure to the conditions stated.

(2) Concrete in contract with alkali waters should be made with aggregates inert to the alkalies in the water.

(3) Cinders should not be used for concrete in which reinforcing metal is embedded.

(4) Reinforcing metal should not be painted, but should be thoroughly covered and protected with concrete when in place.

REPORT OF COMMITTEE V—ON TRACK.

J. B. Jenkins, *Chairman;*
Geo. H. Bremner,
H. M. Church,
Garrett Davis,
Raffe Emerson,
J. M. R. Fairbairn,
T. H. Hickey,
E. T. Howson,
L. J. F. Hughes,
J. R. Leighty,
Curtiss Millard,
G. J. Ray, *Vice-Chairman;*
P. C. Newbegin,
F. B. Oren,
H. T. Porter,
E. Raymond,
W. G. Raymond,
L. S. Rose,
H. R. Safford,
C. H. Stein,
F. S. Stevens,
A. H. Stone,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Track respectfully submits its report to the fifteenth annual convention.

Meetings of the whole Committee were held at Chicago on June 10th and November 17th, in addition to the meetings of the two Sub-Committees.

In addition to the three subjects assigned by the Board of Direction, your Committee undertook a study of speeds of trains on curves and the relation between speeds of trains and the lead curves and switch angles of turnouts; also a study of standard plans of guard rails.

These subjects were reassigned to two Sub-Committees, all subjects excepting that of Economics in Track Labor being assigned to Sub-Committee No. 1, while that subject was assigned to Sub-Committee No. 2; the different subjects assigned to Sub-Committee No. 1 were again assigned to special committees of two or three members each, with the understanding that each member of the Sub-Committee was to contribute all he could to the work of each special committee.

MAIN LINE TURNOUTS AND CROSSOVERS.

SUB-COMMITTEE NO. 1.

H. T. Porter, *Chairman;*
T. H. Hickey,
L. J. F. Hughes,
J. R. Leighty,
Curtiss Millard,
E. Raymond,
G. J. Ray,
L. S. Rose,
F. S. Stevens,
A. H. Stone.

H. T. Porter and T. H. Hickey, Special Committee.

Your Committee has prepared typical plans for Nos. 8, 11 and 16 main line crossovers. It has also made a study of double-slip crossings, obtaining data as to the practice and standards of various railroads and

manufacturers, and has compiled and submits herewith a table of dimensions of various designs of such crossings, including dimensions suggested by your Committee. It has also prepared and presents, as information and progress report, typical plans for Nos. 8, 11 and 16 double-slip switches and a plan by the Cleveland, Cincinnati, Chicago & St. Louis Railway for a No. 8 double-slip switch, the feature of which is the staggering of the switch points. Your Committee is studying and reports progress on plans for double crossovers or scissors.

The basis for the preparation of these typical plans was to make as much of them as possible correspond with the Table of Practical Leads and with the Typical Plans of Turnouts, which have been adopted by the Association; therefore, the standard frog was used for the rigid end frogs of the crossings, and the switches are the standard recommended for the corresponding frog. The tie spacing under frog and switch is made to correspond as nearly as consistent with the tie spacing under corresponding frogs and switches in turnouts.

The distance from end of frog to switch point of double-slip switches has been taken at about the minimum that should be used and still have the necessary spread between rails at points, this spread being about 14 inches. Taking the above distance as a minimum gives the greatest length from switch point to switch point, and correspondingly the easiest curve through the turnout.

Preliminary plans have also been made and studies for the double crossing or scissors, but your Sub-Committee reports only progress on them and considers that further study is required.

SPEEDS OF TRAINS ON CURVES AND TURNOUTS.

F. S. Stevens and G. J. Ray, Special Committee.

Your Committee reports that it has made a study of speeds through turnouts and around curves, has made calculations and has prepared diagrams showing the results of these calculations, which are presented herewith.

RELATION OF SPEED TO POINT OF INTERSECTION OF RESULTANT OF FORCES WITH PLANE OF TRACK.

Let $M =$ the mass of a body,
$g =$ the acceleration of gravity,
$W =$ the weight of the body.

From the law of the weight of bodies,

$$W = M g.$$

Let $R =$ the radius of rotation,
$v =$ the velocity in feet per second,
$C =$ centrifugal force.

From the law of centrifugal force,

$$C = \frac{M v^2}{R};$$

Hence $$\frac{C}{W} = \frac{v^2}{R g} \text{. . . . .(1)}$$

Let V = velocity in miles per hour,
D = degree of curve.

Then $$v = \frac{5280\, V}{3600},$$

$$R = \frac{5730}{D}, \text{. . . . .(approx.)}$$

$$g = 32.16.$$

Substituting these values in equation (1)

$$\frac{C}{W} = .000\,011\,67\, D\, V^2 \text{ . . . .(2)}$$

$$\log = 5.067\,192 - 10$$

Let G = gage of track,
E = elevation for curvature,
H = height of center of gravity above top of rail,
F = resultant of forces,
A = distance from center of track to intersection of F with plane of track,
B = distance from center of gravity to axis of track,
x = cant of track = angle of axis of track with the vertical,
y = angle of resultant of forces with axis of track.

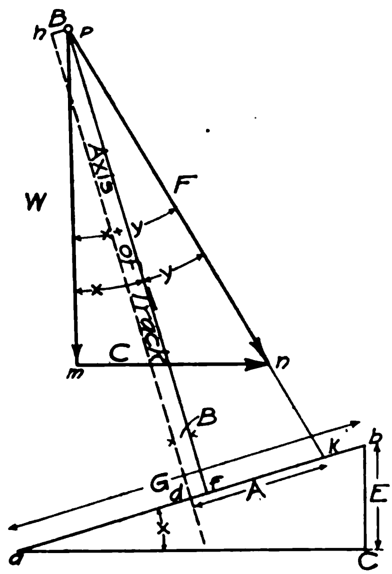


FIG. 1.

In Fig. 1, $ab = G$

$bc = E$

$hd = pf = H$

$pn = F$

$dk = A$

$hp = df = B$

angle $bac = mpf = x$

and angle $fpk = y$

From the right triangles

$$\sin x = \frac{E}{G} \quad \dots\dots\dots\dots (3)$$

$$\tan y = \frac{A\text{-}B}{H} \quad \dots\dots\dots\dots (4)$$

$$\tan (x + y) = \frac{C}{W} = .000\,011\,67\, D\, V^2 \quad \dots\dots\dots\dots (5)$$

In using the above formulas we not only need to know the values of H and B, but we should also give consideration as to the proper value to assign to G.

Heights of centers of gravity of recently constructed engines and tenders are given in the following tables, furnished by the Baldwin and American companies.

AMERICAN LOCOMOTIVE COMPANY.

VERTICAL CENTER OF GRAVITY OF ENGINES

Order No.	Road	Class	Weight	Cylinders	Driving Wheel Diam.	Center of Gravity from Rail
S 846	Missouri Pac.	462	256,000	26 x26″	73″	76[illegible]″
S 831	Missouri Pac.	282	275,000	27 x30″	63″	71″
B 1234	Missouri Pac.	280	209,600	22 x30″	63″	72″
S 310	B. & O.	462	229,500	22 x28″	74″	70″
S 496	N. Y. C.	280	236,000	23 x32″	63″	72″
S 461	L. S. & M. S.	462	261,500	22 x28″	79″	75[illegible]″
S 203	Grand Trunk	460	182,000	20 x26″	73″	64[illegible]″
S 42	B. & O.	280	186,000	21 x30″	57″	68[illegible]″
S 286	Pennsylvania	262	#1 230,000 #2 234,500	22[illegible]x28″	80″	74[illegible]″
P 405	B. & O.	280	193,500	22 x28″	56″	60[illegible]″
S 351	M. & St. L.	260	150,500	20 x26″	64″	60[illegible]″
S 73	B. & O.	442	180,000	22 x28″	80″	70[illegible]″

VERTICAL CENTER OF GRAVITY OF TENDERS

Order No.	Road	Capacity	Tank Type	Center of Gravity
S 848	Erie	9000	Vanderbilt	76[illegible]″
J 1720	Erie	8500	Water Bottom	77″
S 695	Experimental	8000	Water Bottom	70″

THE BALDWIN LOCOMOTIVE WORKS.

APPROXIMATE HEIGHT OF CENTER GRAVITY OF STANDARD GAGE LOCOMOTIVES AND TENDERS RECENTLY CONSTRUCTED

Type of Locomotive	Engine in Working Order		Tender Loaded	
	Weight Pounds	Height C. of G. Inches	Weight Pounds	Height C. of G. Inches
4-6-2	267,000	80	147,000	60
2-8-0	217,000	74	177,000	60
2-8-2	265,000	78	167,000	57
2-8-2	275,000	76	184,000	62
2-8-2	284,000	78	167,000	65
2-8-2	286,000	75	154,000	55
2-8-2	310,000	75	175,000	56
2-8-2	322,000	76	157,000	62
2-10-2	298,000	78	185,000	62
2-10-2	356,000	77	160,000	55
0-6-6-0	360,000	77	140,000	62
0-8-8-0	409,000	84	170,000	61
2-8-8-0	450,000	80	154,000	64

The engine has a lateral swing or play due to compression of springs, play on axle, difference between gages of wheels and track, worn flanges, worn rail and widening of gage of track on curves, although the last factor is usually more than neutralized by the distance the center of the wheel-base is held away from the outer rail by curvature.

Although the flange of the rear wheel of an engine traveling at slow speed is never observed to be in contact with the outer rail when there is any lateral play, yet it would be unsafe to assume that such were the case at speeds high enough to be near the limit of safety, and it is entirely possible that the line of the wheels may at times coincide with a chord of the rail drawn from the point of contact of the front wheel to that of the rear wheel. Hence it has been assumed that the minimum distance that the center of the outer wheel-base is held away from the outer rail equals the middle ordinate of a curve whose chord equals the length of wheel-base.

Under compression of springs, the upper part of the engine revolves about a horizontal central axis about 40 inches above the rail; the maximum vertical movement of the springs from normal position is about $\frac{1}{4}$ inch, at a distance of about 2 feet 4 inches from the center of the engine; the resulting swing from one side to the other of a point in the vertical axis of the engine, 84 inches above the rail, is

$$2 \times \frac{84-40}{28} \times \frac{1}{4}\text{ in.} = \frac{11}{14}\text{ in.} = \frac{13}{16}\text{ in.}$$

Gage of wheels, back to back of flanges..................	$53\frac{3}{8}$ in.
Add two flanges of minimum thickness..................	2
Minimum gage of wheels, front to front of flanges.......	$55\frac{3}{8}$ in.
Gage of track..	$56\frac{1}{2}$
Maximum play between worn wheels and standard gage track....	$1\frac{1}{8}$ in.
Play on axle..	$\frac{5}{8}$
Total lateral play not affected by degree of curve...........	$2\frac{9}{16}$ in.

The distance B equals $\frac{1}{2}$ of $2\frac{9}{16}$ in., plus half the widening of gage due to worn rail, plus half the widening of gage for curvature, less the middle ordinate of the curve for a length equal to the wheel-base.

For example, with a 12-foot wheel-base:

When $D =$ 1 degree, $B = 1\frac{9}{32}$ in. $+ \frac{1}{4}$ in. $+$ 0 in. $- \frac{1}{32}$ in. $= 1\frac{1}{2}$ in.
" $D =$ 4 degrees, $B = 1\frac{9}{32}$ in. $+ \frac{1}{4}$ in. $+$ 0 in. $- \frac{5}{32}$ in. $= 1\frac{3}{8}$ in.
" $D =$ 8 degrees, $B = 1\frac{9}{32}$ in. $+ \frac{1}{4}$ in. $+$ 0 in. $- \frac{5}{16}$ in. $= 1\frac{7}{32}$ in.
" $D =$ 15 degrees, $B = 1\frac{9}{32}$ in. $+ \frac{1}{4}$ in. $+ \frac{1}{4}$ in. $- \frac{9}{16}$ in. $= 1\frac{7}{32}$ in.
" $D =$ 19 degrees, $B = 1\frac{9}{32}$ in. $+ \frac{1}{8}$ in. $+ \frac{3}{8}$ in. $- \frac{23}{32}$ in. $= 1\frac{1}{16}$ in.
" $D =$ over 19 degrees, $B =$ less than

Thus, B varies from a possible value of $1\frac{1}{2}$ in. for a 1-degree curve to a possible $1\frac{7}{32}$ in. for an 8-degree curve, remains constant, on account of widening of gage for curvature, up to 15 degrees and then decreases.

As high speeds are necessarily encountered on the lighter curves and lower speeds on the sharper curves, any change in the assumed value of B would cause a considerable change in the results of calculations of speeds for the lighter curves, but would have a comparatively slight effect on the results for the sharper curves. Hence no great error will result, and such errors as do result will be on the safe side, if the maximum value of B is used throughout.

The value of G may also vary from $56\frac{1}{2}$ in., the standard gage, to $57\frac{1}{2}$ in.; but under the conditions which will give B its maximum values G will have the following values:

$D =$ 1 degree to 8 degrees .... $G = 57$ in.
$D =$ 15 degrees or over .... $G = 57\frac{1}{2}$ in.

It might appear at first thought that a wider gage would increase the stability of an engine, and that, therefore, the minimum value of G should be used in all calculations, in order to keep on the safe side. Such would be the case if the gage of the wheels were widened at the same time as the gage of the track. But a little consideration will show that the widening of the gage does not affect the stability of the engine, either one way or the other, when it is at the point of overturning, while a wider gage actually decreases the stability of the engine when the resultant of forces falls within the gage line.

Referring to Fig. 1, when the engine is on the point of overturning $\tan y = \dfrac{\frac{1}{2}G - B}{H} = \dfrac{fb}{pf}$; any widening of gage affects ab and af equally, leaving fb constant; hence y is constant, and the speed necessary to overturn is not affected.

But when the engine is in a given phase of stable equilibrium, as for instance, when two-thirds of its weight is carried by the outer rail, $\tan y = \dfrac{1/6\,G - B}{H} = \dfrac{fk}{pf}$; $fk = fb - kb$; fb is constant as before, while $kb = \frac{1}{3}G$; hence any increase in G decreases fk by one-third that amount;

y is decreased and the speed necessary to produce the given condition is decreased.

If, however, we take B uniformly at its maximum value of $1\frac{1}{2}$ in., we can also take G at a uniform value of 57 in.; for, although G may be $\frac{1}{2}$-in. too small and A may be $\frac{1}{16}$-in. too small, when D is 15 degrees or over, B has been taken $\frac{3}{32}$ to $\frac{7}{16}$ in. too large; fk and the angle y are too small, and the speed calculated to produce the given distribution of weights is still on the safe side.

A number of calculations were made, using the theoretical values of B and G, and compared with the results obtained by giving B its maximum value of $1\frac{1}{2}$ in. and G a constant value of 57 in.; the differences were found to be too trifling to warrant the more complex calculations, and the results obtained by assigning the latter values were all on the safe side. Hence, in calculating the results which are submitted, it has been assumed that

$$B = 1\tfrac{1}{2} \text{ in.}$$

and

$$G = 57 \text{ in.}$$

To ascertain the speed which will cause the resultant of force to intersect the plane of the track at any given point k:

First—Obtain x from equation (3).

Second—Obtain y from equation (4).

Third—Solve equation (5) for V.

SPEEDS OF TRAINS ON CURVES

Height of Center of Gravity 84 in.
Resultant of Forces through Gage Line

Degree of Curve	Elevation in Inches								
	0	1	2	3	4	5	6	7	8
1°	165.9	170.9	175.8	180.6	185.3	190.0	194.7	199.4	204.0
1°30′	135.5	139.5	143.5	147.4	151.3	155.1	159.0	162.8	166.5
2°	117.3	120.8	124.3	127.7	131.1	134.3	137.7	141.0	144.2
2°30′	104.9	108.1	111.2	114.2	117.2	120.1	123.1	126.1	129.0
3°	95.8	98.7	101.5	104.3	107.0	109.7	112.4	115.1	117.8
3°30′	88.7	91.3	94.0	96.5	99.1	101.5	104.1	106.6	109.0
4°	83.0	85.4	87.9	90.3	92.7	95.0	97.4	99.7	102.0
4°30′	78.2	80.6	82.9	85.1	87.4	89.6	91.8	94.0	96.2
5°	74.2	76.4	78.6	80.8	82.9	85.0	87.1	89.2	91.2
6°	67.7	69.8	71.8	73.7	75.7	77.6	79.5	81.4	83.3
7°	62.7	64.6	66.4	68.3	70.1	71.8	73.6	75.3	77.1
8°	58.7	60.4	62.1	63.8	65.5	67.2	68.8	70.5	72.1
9°	55.3	57.0	58.6	60.2	61.8	63.3	64.9	66.4	68.0
10°	52.5	54.0	55.6	57.1	58.6	60.1	61.6	63.0	64.5
12°	47.9	49.3	50.7	52.1	53.5	54.8	56.2	57.5	58.9
14°	44.3	45.7	47.0	48.3	49.5	50.8	52.0	53.8	54.5
16°	41.5	42.7	43.9	45.1	46.4	47.5	48.7	49.8	51.0
18°	39.1	40.3	41.4	42.6	43.7	44.8	45.9	47.0	48.1
20°	37.1	38.2	39.3	40.4	41.4	42.5	43.5	44.6	45.6
25°	33.2	34.2	35.2	36.1	37.1	38.0	38.9	39.9	40.8
30°	30.3	31.2	32.1	33.0	33.8	34.7	35.5	36.4	37.2

SPEEDS OF TRAINS ON CURVES

Height of Center of Gravity 84 in.
Resultant through Edge of Middle Third

Degree of Curve	Elevation in Inches								
	0	1	2	3	4	5	6	7	8
1°	90.3	98.4	105.9	112.9	119.6	125.9	132.0	137.9	143.4
1°30′	73.7	80.3	86.4	92.2	97.6	102.8	107.8	112.6	117.2
2°	63.9	69.6	74.9	79.8	84.5	89.0	93.3	97.5	101.5
2°30′	57.1	62.2	67.0	71.4	75.6	79.6	83.5	87.2	90.8
3°	52.1	56.8	61.1	65.2	69.0	72.7	76.2	79.6	82.9
3°30′	48.3	52.6	56.6	60.3	63.9	67.3	70.6	73.7	76.7
4°	45.2	49.2	52.9	56.5	59.8	62.9	66.0	68.9	71.7
4°30′	42.6	46.4	49.9	53.2	56.4	59.4	62.2	65.0	67.7
5°	40.4	44.0	47.3	50.5	53.5	56.3	59.0	61.7	64.2
6°	36.9	40.2	43.2	46.1	48.8	51.4	53.9	56.3	58.6
7°	34.1	37.2	40.0	42.7	45.2	47.6	49.9	52.1	54.3
8°	31.9	34.8	37.4	39.9	42.3	44.5	46.7	48.7	50.8
9°	30.1	32.8	35.3	37.6	39.8	42.0	44.0	46.0	47.8
10°	28.6	31.1	33.5	35.7	37.8	39.8	41.7	43.6	45.4
12°	26.1	28.4	30.6	32.6	34.5	36.3	38.1	39.8	41.4
14°	24.1	26.3	28.3	30.2	31.9	33.6	35.3	36.8	38.4
16°	22.6	24.6	26.5	28.2	29.9	31.5	33.0	34.5	35.8
18°	21.3	23.2	25.0	26.6	28.2	29.7	31.1	32.5	33.8
20°	20.2	22.0	23.7	25.2	26.7	28.1	29.5	30.8	32.1
25°	18.1	19.7	21.2	22.6	23.9	25.2	26.4	27.6	28.7
30°	16.5	18.0	19.3	20.6	21.8	23.0	24.1	25.2	26.2

SPEED AND UNBALANCED ELEVATION FOR CURVATURE.

The comfort of a passenger on a train, which passes over a curve or through a turnout at high speed, is not dependent on the height of the center of gravity of the engine which draws his train, or of the car in which he is riding, nor is it dependent on the point where the resultant of forces intersects the plane of the track.

But the comfort of the passenger is much affected by the condition of the track in the matter of surface and line, and the disturbed equilibrium of the passenger due to centrifugal force uncompensated by the cant of the track.

The relation of speed to the condition of the track cannot be reduced to formula, tabulated nor shown on a diagram, but the relation of equilibrium to speed can very readily be shown.

There are nearly as many opinions as there are individuals as to what constitutes a comfortable speed on curves; but by tabulating speeds which will produce a certain fixed degree of disturbance of equilibrium, we can at least furnish a basis for comparison between speed and comfortable riding.

Referring to Fig. 1, if $y=3$ degrees, the track will lack sufficient cant to neutralize the centrifugal force by 3 degrees; a difference of 3 degrees in the cant of the track is very closely equivalent to a difference of 3 inches in elevation of the outer rail. Hence, if the amount of discomfort can be measured by the degree of angle, which the resultant of forces makes with the axis of the car, it can be measured by number of

inches of unbalanced elevation. In other words, a passenger riding over track elevated 1 inch at a speed requiring an elevation of 4 inches, should experience the same amount of discomfort as when riding over track elevated 7 inches at a speed requiring an elevation of 10 inches.

Your Committee has calculated tables of speeds of trains through curves and turnouts with unbalanced elevations of 3 inches. These calculations were made from the formulas

$$\sin(x+y)=\frac{E+3}{56.5}\text{ and }V=\sqrt{\frac{\tan(x+y)}{.000\,011\,67\,D}},$$

in which E = actual elevation for curvature.

SPEEDS OF TRAINS ON CURVES

Three Inches of Unbalanced Elevation.
Those Speeds of Trains on Curves having an Elevation of 3 Inches less than the Theoretical Elevation.*
All Heights of Center of Gravity.

Degree of Curve	Actual Elevation in Inches								
	0	1	2	3	4	5	6	7	8
1°	67.5	78.0	87.2	95.6	103.4	110.7	117.6	124.1	130.4
1°30′	55.1	63.7	71.2	78.1	84.4	90.4	96.0	101.3	106.5
2°	47.7	55 1	61.7	67.6	73.1	78.3	83.1	87.8	92.2
2°30′	42.7	49.3	55.2	60.5	65.4	70.0	74.3	78.5	82.5
3°	39.0	45.0	50.4	55.2	59.7	63.9	67.9	71.7	75.3
3°30′	36.1	41.7	46.6	51.1	55.3	59.2	62.8	66.3	69.7
4°	33.7	39.0	43.6	47.8	51.7	55.3	58.8	62.1	65.2
4°30′	31.8	36.8	41.1	45.1	48.8	52.2	55.4	58.5	61.5
5°	30.2	34.9	39.0	42.8	46.2	49.5	52.6	55.5	58.3
6°	27.6	31.8	35.6	39.0	42.2	45.2	48.0	50.7	53.2
7°	25.5	29.5	33.0	36.1	39.1	41.8	44.4	46.9	49.3
8°	23.9	27.6	30.8	33.8	36.6	39.1	41.6	43.9	46.1
9°	22.5	26.0	29.1	31.9	34.5	36.9	39.2	41.4	43.5
10°	21.3	24.7	27.6	30.2	32.7	35.0	37.2	39.3	41.2
12°	19.5	22.5	25.2	27.6	29.9	32 0	33.9	35.8	37.6
14°	18.0	20.8	23.3	25.6	27.6	29.6	31.4	33.2	34.8
16°	16.9	19.5	21.8	23.9	25.9	27.7	29.4	31.0	32.6
18°	15.9	18.4	20.6	22.6	24.4	26.1	27.7	29.2	30.7
20°	15.1	17.4	19.5	21.4	23.1	24.7	26.3	27.8	29.2
25°	13.5	15.6	17.4	19.1	20.7	22.1	23.5	24.8	26.1
30°	12.3	14.2	15.9	17.5	18.9	20.2	21.5	22.6	23.8

*See text under "Speed and Unbalanced Elevation for Curvature."

The motion through a straight switch-point being angular, there can be no direct comparison of speed through the switch-point with that through the lead curve. In order to give a rough basis for comparison between the various switch-points and the various lead curves, the speeds through the switch-points are figured for curves whose central angle equals the switch angle, and the length of whose chord equals the length of switch-point. On the above basis, with a wheel-base or truck-center distance equal to or longer than the switch-point, the rate of turning would equal that through the lead curve.

SPEEDS OF TRAINS THROUGH TURNOUTS

Height of Center of Gravity 84 in.
Resultant of Forces through Gage Line.

Frog No.	Degree of Lead Curve	Length of Switch	Elevation in Inches 0	1	2	3
4-6		11	34.1	35.1	36.1	37.1
4	53°42'24"		22.6	23.3	24.0	24.6
5	33°19'57"		28.7	29.6	30.4	31.3
6	21°43'04"		35.9	37.0	38.0	39.0
7-10		16.5	51.1	52.7	54.2	55.7
7	15°52'29"		41.7	43.0	44.2	45.4
8	11°46'27"		48.4	49.8	51.2	52.6
9	9°28'42"		53.9	55.5	57.1	58.7
9½	8°14'45"		57.8	59.5	61.2	62.9
10	7°15'18"		61.6	63.5	65.3	67.1
11-14		22	68.2	70.3	72.2	74.2
11	6°12'47"		66.6	68.6	70.5	72.4
12	5°12'59"		72.7	74.8	77.0	79.1
15-24		33	102.3	105.4	108.4	111.3
15	3°17'10"		91.1	94.3	97.0	[illegible]
16	2°52'59"		97.7	100.6	103.5	[illegible]
18	2°14'31"		110.8	114.1	117.4	[illegible]
20	1°45'32"		125.1	128.9	132.5	[illegible]
24	1°10'21"		153.3	157.9	162.4	[illegible]

SPEEDS OF TRAINS THROUGH TURNOUTS

Height of Center of Gravity 84 in.
Resultant Through Edge of Middle Third.

Frog No.	Degree of Lead Curve	Length of Switch	Elevation in Inches 0	1	2	3
4-6		11	18.6	20.2	21.8	23.3
4	53°42'24"		12.3	13.4	14.4	15.4
5	33°19'57"		15.6	17.0	18.3	19.5
6	21°43'04"		19.5	21.3	22.9	24.4
7-10		16.5	27.8	30.3	32.6	34.8
7	15°52'29"		22.7	24.7	26.6	28.4
8	11°46'27"		26.3	28.7	30.9	32.9
9	9°28'42"		29.3	32.0	34.4	36.7
9½	8°14'45"		31.4	34.3	36.9	39.3
10	7°15'18"		33.5	36.5	39.3	41.9
11-14		22	37.1	40.4	43.5	46.4
11	6°12'47"		36.2	39.5	42.5	45.3
12	5°12'59"		39.5	43.1	46.4	49.4
15-24		33	55.7	60.7	65.3	69.6
15	3°17'10"		49.8	54.3	58.4	62.3
16	2°52'59"		53.2	57.9	62.4	66.5
18	2°14'31"		60.3	65.7	70.7	75.4
20	1°45'32"		68.1	74.2	79.8	85.1
24	1°10'21"		83.4	90.9	97.8	104.3

SPEEDS OF TRAINS THROUGH TURNOUTS

Three Inches of Unbalanced Elevation.

All Heights of Center of Gravity.

Those Speeds of Trains through Turnouts having an Elevation of 3 Inches less than the Theoretical Elevation.*

Frog No.	Degree of Lead Curve	Length of Switch	Actual Elevation in Inches			
			0	1	2	3
4–6		11	13.9	16.0	17.9	19.6
4	53°42′24″		9.2	10.6	11.9	13.0
5	33°19′57″		11.7	13.5	15.1	16.6
6	21°43′04″		14.6	16.9	18.9	20.7
7-10		16.5	20.8	24.0	26.9	29.5
7	15°52′29″		17.0	19.6	21.9	24.0
8	11°46′27″		19.7	22.7	25.4	27.9
9	9°28′42″		21.9	25.3	28.3	31.1
9½	8°14′45″		23.5	27.1	30.4	33.3
10	7°15′18″		25.1	29.0	32.4	33.5
11–14		22	27.7	32.0	35.9	39.3
11	6°12′47″		27.1	31.3	35.0	38.4
12	5°12′59″		29.5	34.1	38.2	41.9
15–24		33	41.6	48.1	53.8	59.0
15	3°17′10″		37.2	43.0	48.1	52.8
16	2°52′59″		39.7	45.9	51.4	56.3
18	2°14′31″		45.1	52.1	58.3	63.9
20	1°45′32″		50.9	58.8	65.8	72.1
24	1°10′21″		62.3	72.0	80.6	88.3

*See text under "Speed and Unbalanced Elevation for Curvature."

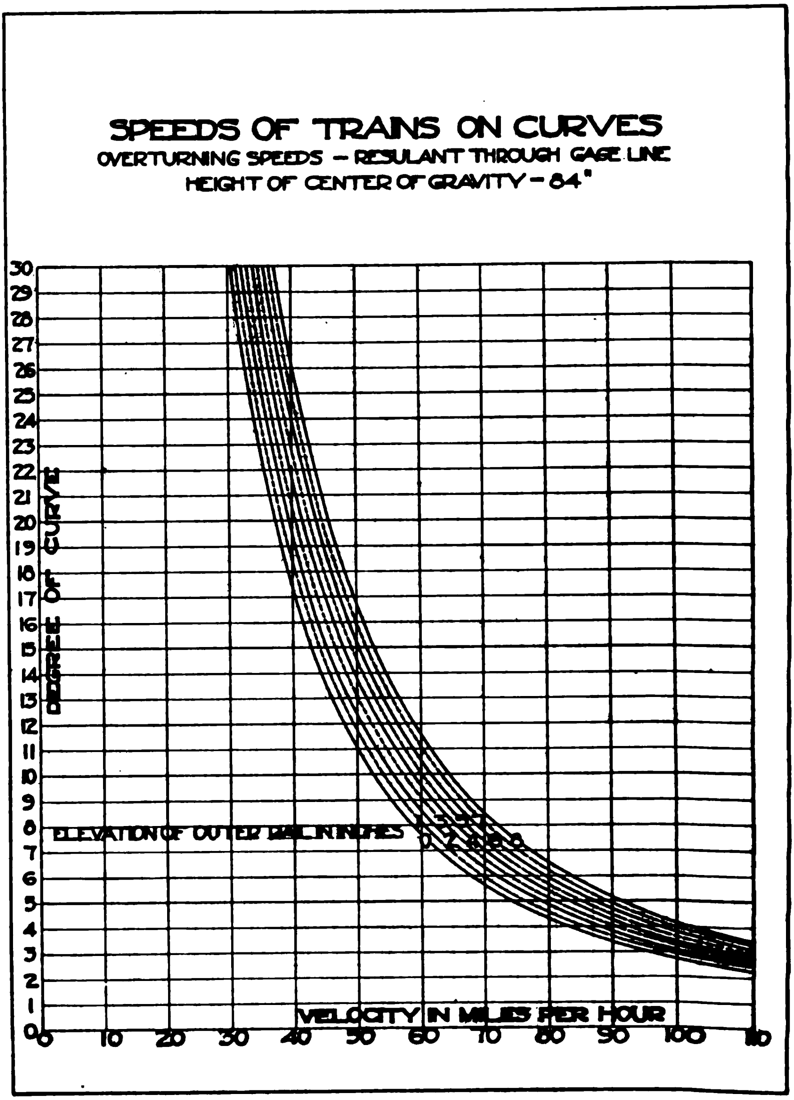
SPEEDS OF TRAINS THROUGH LEVEL TURNOUTS

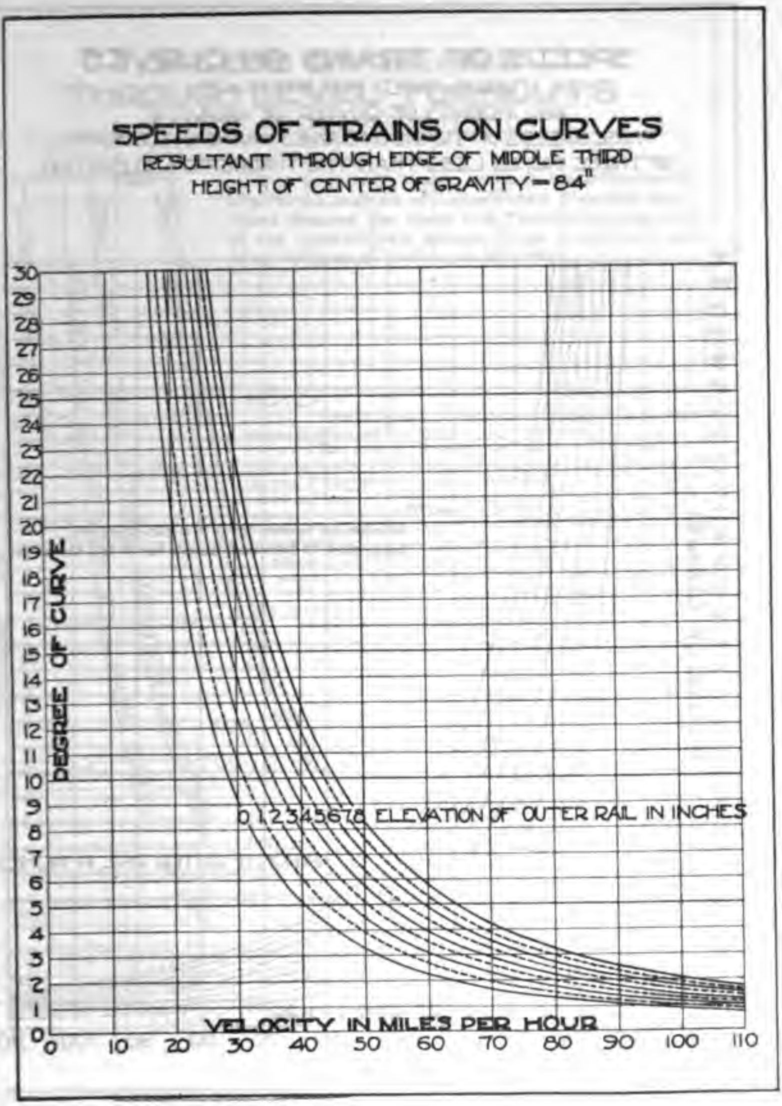
Height of Center of Gravity 84 in.

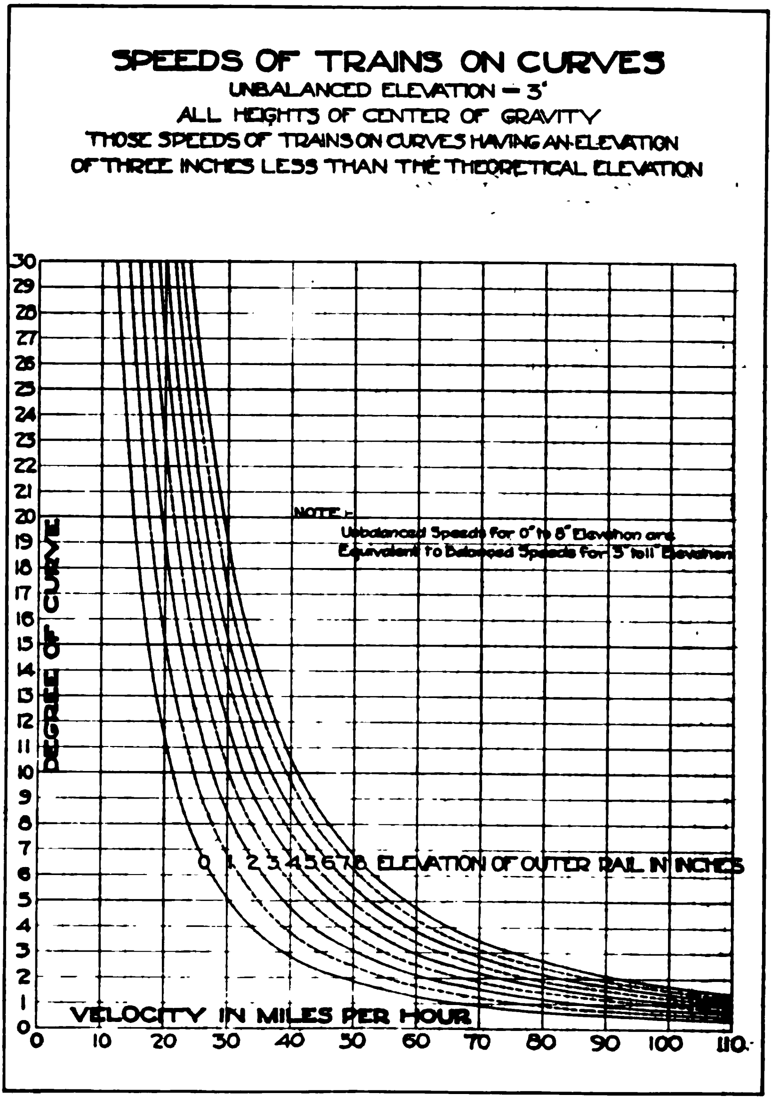
Resultant Through Points at Varying Distances from Center Line.

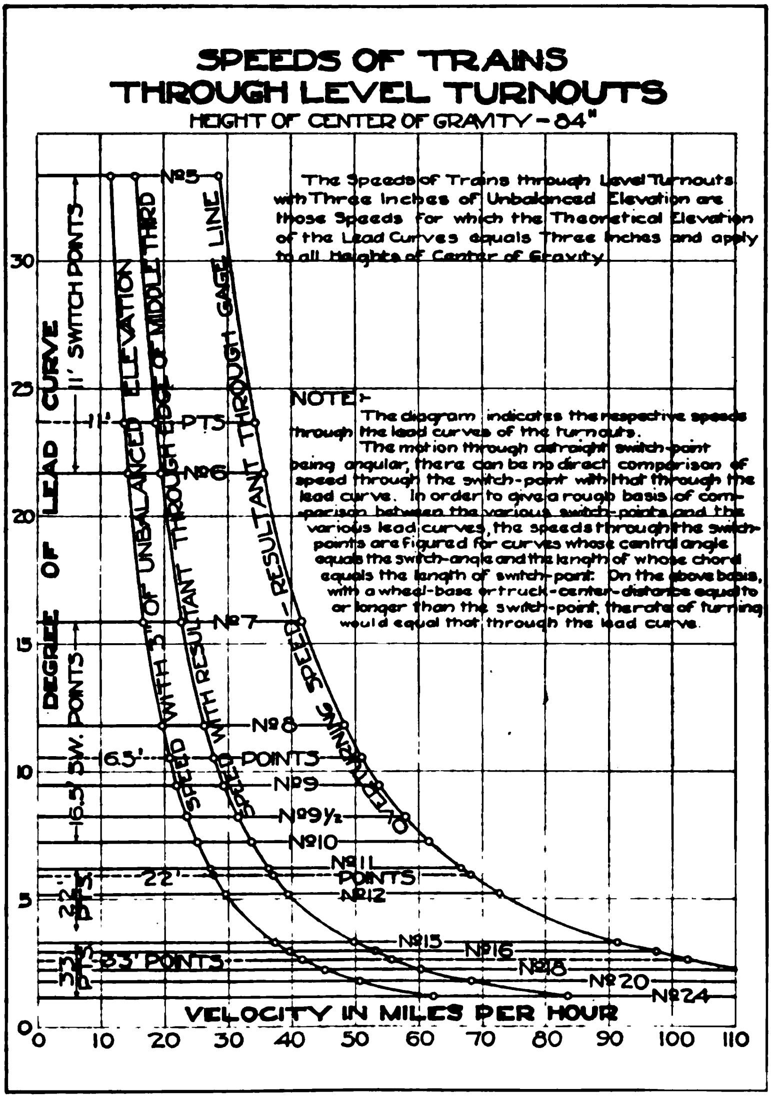
Frog No.	Length of Switch	Distance of Resultant from Center Line of Track						
		2″	4″	6″	8″	10″	12″	14″
4–6	11	4.6	10.4	13.9	16.7	19.1	21.3	23.2
4		3.1	6.9	9.2	11.1	12.7	14.1	15.4
5		3.9	8.7	11.7	14 1	16.1	17.9	19.5
6		4.9	10.9	14.6	17.6	20.1	22.4	24.4
7-10	16.5	7.0	15.6	20.9	25.1	28.7	31.9	34.8
7		5.7	12.7	17.0	20.5	23.4	26.0	28.4
8		6.6	14.7	19 7	23.7	27.1	30.1	32.9
9		7.3	16.4	22.0	26.4	30.2	33.6	36.7
9½		7.9	17.6	23.6	28.4	32.4	36.0	39.3
10		8.4	18.7	25.2	30.2	34.6	38.4	41.9
11–14	22	9.3	20.7	27.8	33.5	38.3	42.5	46.4
11		9.1	20.3	27.2	33.4	37.4	41 5	45.3
12		9.9	22.1	29.7	35.6	40.8	45.3	49.4
15–24	33	13.9	31.1	41.8	50.2	57.4	63.8	69.6
15		12.5	27.9	37.4	44.9	50.2	57.1	62.3
16		13.3	29.7	39.9	47.9	54.8	60.9	66.5
18		15.1	33.7	45.2	54.3	62.2	69.1	75.4
20		17.0	38.1	51.1	61.4	70.2	78.0	85 1
24		20.9	46.6	62.6	75.2	86.0	95.6	104.3

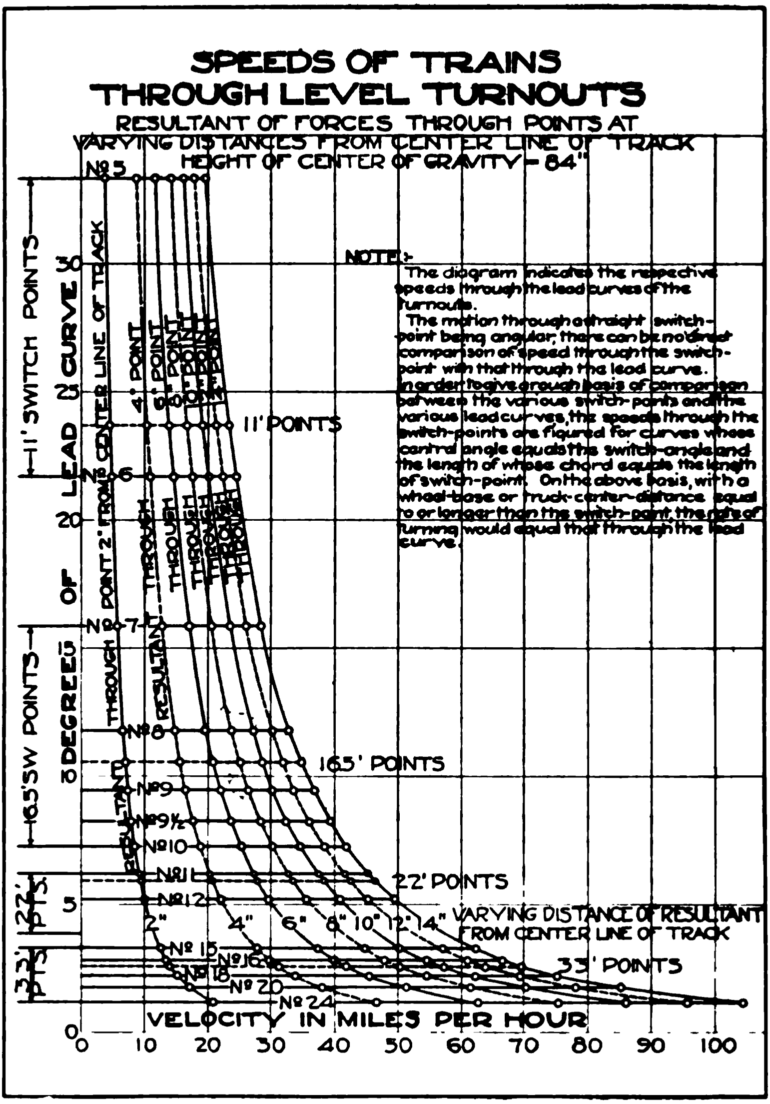
The speeds in the foregoing tables are graphically represented in the following diagrams.


SPEEDS OF TRAINS ON CURVES
OVERTURNING SPEEDS — RESULANT THROUGH GAGE LINE
HEIGHT OF CENTER OF GRAVITY — 84"
DEGREE OF CURVE
ELEVATION OF OUTER RAIL IN INCHES
VELOCITY IN MILES PER HOUR
0 10 20 30 40 50 60 70 80 90 100 110
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


SPEEDS OF TRAINS ON CURVES
RESULTANT THROUGH EDGE OF MIDDLE THIRD
HEIGHT OF CENTER OF GRAVITY = 84"
DEGREE OF CURVE
0 1 2 3 4 5 6 7 8 ELEVATION OF OUTER RAIL IN INCHES
VELOCITY IN MILES PER HOUR
0 10 20 30 40 50 60 70 80 90 100 110
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


SPEEDS OF TRAINS ON CURVES
UNBALANCED ELEVATION — 3"
ALL HEIGHTS OF CENTER OF GRAVITY
THOSE SPEEDS OF TRAINS ON CURVES HAVING AN ELEVATION
OF THREE INCHES LESS THAN THE THEORETICAL ELEVATION
NOTE:-
Unbalanced Speeds for 0" to 8" Elevation are
Equivalent to Balanced Speeds for 3" to 11" Elevation
DEGREE OF CURVE
0 1 2 3 4 5 6 7 8 ELEVATION OF OUTER RAIL IN INCHES
VELOCITY IN MILES PER HOUR
0 10 20 30 40 50 60 70 80 90 100 110
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


SPEEDS OF TRAINS
THROUGH LEVEL TURNOUTS
HEIGHT OF CENTER OF GRAVITY – 84"
The Speeds of Trains through Level Turnouts with Three Inches of Unbalanced Elevation are those Speeds for which the Theoretical Elevation of the Lead Curves equals Three Inches and apply to all Heights of Center of Gravity.
NOTE:-
The diagram indicates the respective speeds through the lead curves of the turnouts.
The motion through a straight switch-point being angular, there can be no direct comparison of speed through the switch-point with that through the lead curve. In order to give a rough basis of comparison between the various switch-points and the various lead curves, the speeds through the switch-points are figured for curves whose central angle equals the switch-angle and the length of whose chord equals the length of switch-point. On the above basis, with a wheel-base or truck-center-distance equal to or longer than the switch-point, the rate of turning would equal that through the lead curve.
DEGREE OF LEAD CURVE
11' SWITCH POINTS
16.5' SW. POINTS
SPEED WITH 3" OF UNBALANCED ELEVATION
SPEED WITH RESULTANT THROUGH EDGE OF MIDDLE THIRD
OVERTURNING SPEED – RESULTANT THROUGH GAGE LINE
Nº5
11' PTS
Nº6
Nº7
Nº8
16.5' POINTS
Nº9
Nº9½
Nº10
Nº11
22' POINTS
Nº12
Nº15
Nº16
33' POINTS
Nº18
Nº20
Nº24
VELOCITY IN MILES PER HOUR
0 5 10 15 20 25 30
0 10 20 30 40 50 60 70 80 90 100 110


SPEEDS OF TRAINS
THROUGH LEVEL TURNOUTS
RESULTANT OF FORCES THROUGH POINTS AT
VARYING DISTANCES FROM CENTER LINE OF TRACK
HEIGHT OF CENTER OF GRAVITY – 84"
NOTE:-
The diagram indicates the respective speeds through the lead curves of the turnouts.
The motion through a straight switch-point being angular, there can be no direct comparison of speed through the switch-point with that through the lead curve.
In order to give a rough basis of comparison between the various switch-points and the various lead curves, the speeds through the switch-points are figured for curves whose central angle equals the switch-angle and the length of whose chord equals the length of switch-point. On the above basis, with a wheel-base or truck-center-distance equal to or longer than the switch-point, the rate of turning would equal that through the lead curve.
11' SWITCH POINTS
16.5' SW POINTS
22' PTS
33' PTS
DEGREES OF LEAD CURVE
RESULTANT THROUGH POINT 2' FROM CENTER LINE OF TRACK
RESULTANT THROUGH 4' POINT
11' POINTS
16.5' POINTS
22' POINTS
33' POINTS
№ 5
№ 6
№ 7
№ 8
№ 9
№ 9½
№ 10
№ 11
№ 12
№ 15
№ 16
№ 18
№ 20
№ 24
2" 4" 6" 8" 10" 12" 14" VARYING DISTANCE OF RESULTANT FROM CENTER LINE OF TRACK
VELOCITY IN MILES PER HOUR
0 10 20 30 40 50 60 70 80 90 100
0 5 10 15 20 25 30

By dividing the speeds in the above tables by the frog numbers, the result for each table is found to be nearly a constant. Hence, when the height of center of gravity is 84 inches and the elevation $= 0$ inches, the speeds have the following simple arithmetical relations to the frog numbers when the turnouts are level:

Resultant through gage line—speed $= 6.1\ N\pm$.

Resultant through edge of middle third—speed $= 3.3\ N\pm$.

Three inches unbalanced elevation—speed $= 2.46\ N\pm$.

Other equally simple relations can be figured for other heights of center of gravity. The speed for three inches of unbalanced elevation is not affected by the height of center of gravity.

As nearly as can be compared (by assuming the switch-point as a chord of a curve whose central angle equals the switch angle) the corresponding speeds through the switches are $3.1\ S$, $1.69\ S$ and $1.26\ S$, respectively, in which S is the length of the switch-point. On such an assumption the length of the switch-point should approximate double the frog number, as stated in the report of this Committee in Vol. 13 of Proceedings, p. 373.

The assumption, for the purpose of comparison, that a switch-point is equivalent to a curve of equal length subtending an angle equal to the switch angle is a purely arbitrary one; it would be true only if the curve were exceedingly kinky and consisted of short tangents, whose lengths equaled the lengths of switch-point.

Such an assumption is commonly made, however, evidently under the belief that the center of gravity of the engine traverses a more or less regular curve in the direction of the deflection of the switch-point. It does traverse a curve, it is true; but the direction of the curve is opposite to that of the switch-point; in other words, the curve is concave to the rail.

The middle ordinate of the curve traversed by the middle point in the wheel-base is equal to half the length of wheel-base times the difference between the tangent and the sine of half the switch angle, as will be clearly seen by inspection of Fig. 2.

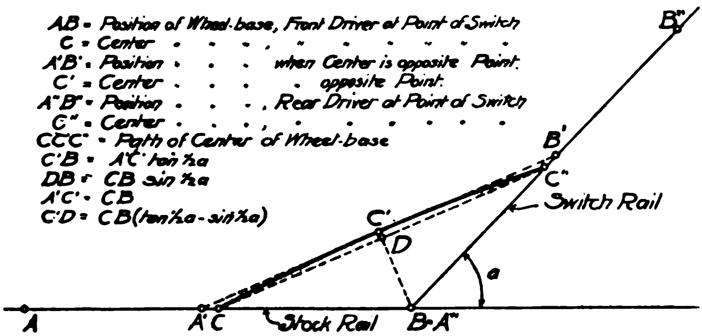


Fig. 2.

The middle ordinate of this curve is so small that the path traversed by any point in the engine, in passing over a switch-point, can be considered as a straight line.

Therefore, it is not a curved, but an angular motion with which we have to deal at the switch-point.

The reactions at the switch-point are rather complex, consisting of both static and dynamic forces.

HORIZONTAL THRUST AT SWITCH-POINT, DUE TO FRICTION.

First, there is a static force in the form of a horizontal thrust, due to the switch-point forcing the engine to move at an angle with the direction of rotation of the wheels, or at an angle with the line of the wheel-base. This probably causes a slipping of all wheels excepting the rear outside or the rear inside wheel, depending on whether the engine is exerting tractive force or not. This horizontal force will vary with the length of wheel-base and with the number of drivers, but can be roughly determined in the following manner:

Assume a 17-foot wheel-base and 6 drivers; the weight on drivers $= W$, and the co-efficient of sliding friction $= c$.

The weight on each driver is then $\frac{W}{6}$ and the resistance to sliding of each of the five sliding wheels is $\frac{c\,W}{6}$.

Taking the distance between points of contact between the rail and the two wheels on an axle at 5 feet, the lever arms of the two slipping wheels on the one side are 8.5 and 17 feet, while those of the three wheels on the other side are 5, 9.86 and 17.72 feet. The sum of the moments of the five slipping wheels is $58.08 \times \frac{c\,W}{6}$.

As the lever arm of the switch-rail acting on the front outer wheel is 17 feet, the resulting horizontal force exerted by the rail on this wheel is $\frac{58.08}{17} \times \frac{c\,W}{6}$ or $0.57\,c\,W$.

With a 22-foot switch-point, the sliding motion of the front outside wheel is 1/44 of the forward motion of the engine and the average sliding motion of the five wheels is $\frac{58.08}{5 \times 17}$ of that of the front outside wheel or .015 times the forward motion of the engine.

Therefore, at a speed of 60 M. P. H., the average sliding motion is at a velocity of only 0.9 M. P. H.

At the moment the sliding begins the friction to be overcome is the friction of repose. The co-efficient of friction of repose between steel tires and steel rails is approximately 0.25. After the sliding begins the co-efficient will drop somewhat, but seldom below that for a velocity of 1 M. P. H.

At the moment sliding begins, which is when the front drivers strike the point of a facing-point switch or the stock rail of a trailing-point switch, the horizontal static pressure on the rail in this particular case will be approximately $0.57 \times 0.25\,W$ or

$$T = 0.14\,W$$

in which T is the approximate horizontal static pressure, and W is the weight on drivers.

T will vary somewhat with the type of engine, but will probably never exceed $0.19\,W$.

In addition to the above static pressure there is a dynamic force, due to the impact of the engine against the stock rail or switch-point, which is being studied by your Committee, and will be made the subject of a future report.

RELATION BETWEEN WORN FLANGES AND WORN SWITCH-POINTS.

L. S. Rose and J. R. Leighty, Special Committee.

Your Committee reports that it has received a number of letters containing only very indefinite information, and that no conclusion has been reached. Your Committee will endeavor to secure further data and will continue the study.

STANDARD PLANS OF GUARD RAILS.

L. J. F. Hughes, E. Raymond and A. H. Stone, Special Committee.

Your Committee has made no progress on this subject, but will continue the study.

ECONOMICS OF TRACK LABOR.

SUB-COMMITTEE NO. 2.

H. R. Safford, *Chairman;*
G. H. Bremner,
H. M. Church,
Garrett Davis,
Raffe Emerson,
J. M. R. Fairbairn,
E. T. Howson,
P. C. Newbegin,
F. B. Oren,
W. G. Raymond,
C. H. Stein.

The Sub-Committee assigned to the subject of Economics of Track Labor has now been in existence for two years. When it was created, a defined program was prepared, calling for a systematic plan of action embracing some nineteen subjects, of which certain ones would be selected for each year's work, the idea being to look ahead to the future and to not lose sight of the relation existing between these subjects, many of them having defined relations.

The general program embraced the following:

(1) A system of reports to measure efficiency of gangs for various

kinds of work and efficiency of various kinds of labor with a view to establishing tangible data to correctly measure efficiency.

(2) A system of reports to establish unit costs of work.

(3) The use of a system of work cards and other means of planning work and keeping records to measure progress.

(4) The development of a plan and system for establishing a thoroughly accurate basis of comparison of track conditions as a means for measuring efficiency—equating for various conditions, such as rails, ballast, ties, drainage, length of track, etc.

(5) A study of the use and efficiency of motor cars for track work.

(6) A study of labor-saving devices.

(7) A study of the method best suited to various kinds of track work, particular reference being made to rail, ballast and tie renewals.

(8) A study of the method of renewing ties, as to the renewal of ties on every mile of track each year or taking a portion of the track each year to avoid disturbing track too often.

(9) A study of the matter of proper season for various kinds of track work.

(10) A study of the organization best suited to carry on the above work as to extra gangs versus section gangs.

(11) The study of the general suggestion to combine under section foremen such work as ordinary maintenance of signals and telegraph lines, rough carpentry, water station repairs, etc.

(12) Proper size of track supervisors' territory.

(13) The establishment of a labor bureau to better control and secure labor.

(14) Training laborers for track work by specially organized gangs for that purpose.

(15) Rates of pay for section labor.

(16) The matter of obtaining good section foremen.

(17) The education of section foremen.

(18) The rates of pay for section foremen.

(19) The proper basis for providing section houses.

The subjects chosen for the first year's work were:

(a) The matter of educating and obtaining good section foremen.

(b) Methods of making programs for work and sequence of work.

The first subject was discussed to a point permitting a definite conclusion to be reached.

The second subject was not concluded.

The subjects assigned for this year's work were:

(1) The consideration of the idea of extending the scope of duties of a section foreman to embrace certain other works now generally handled by other classes of labor in an endeavor to effect the following:

(a) A saving due to the lost motion of mechanics traveling great distances to perform very simple work, resulting in unnecessary cost.

(b) A saving in delay in getting more prompt action in such work.

(2) The study and development of a system for equating track values to enable:

(a) A more efficient track maintenance as a result of establishing accurate units of service required.

(b) A more equitable method of apportioning monies for track maintenance.

SUBJECT I.

At a meeting held in Buffalo, the Sub-Committee decided to put out a number of inquiries to determine what had been done by other roads in this connection, and circulars were sent out to the membership, as follows:

"The Committee on Track is conducting a study to determine the practicability and advantage of the suggestion being followed by some roads of extending the scope of section foremen's duties to embrace some classes of work now being handled by representatives from other departments.

"The basic feature is an economic one and the result hoped for seems to be a reduction in maintenance expense by having section foremen do such things as emergency repairs to platforms, stock pens, track bonding, battery renewals, telegraph line repairs, etc., the general idea being to reduce, as far as possible, the expense occasioned by high-priced men moving over the road with great loss of time, when only a small amount of work of simple character is required.

"The Committee is desirous of obtaining all possible information from railroads where this has been tried, and in addition to get the opinion of other members of the Association, whether or not based upon actual experiment.

"The Committee would, therefore, appreciate replies to the enclosed circular."

CIRCULAR.

Has your road put into effect any definite plan or conducted any tests or experiments in the direction of extending the scope of Section Foremen's duties to embrace work or portions of work generally done by other than section forces, such as rough carpentry on bridges and buildings, simple repairs to water plants, maintenance of signals, repairs to telegraph lines, etc.?

If so, to what extent?

(a) Length of territory on which it is in effect,
(b) Single or double track line.
(c) Main line or branch line.
(d) Character of track:
    1. General alinement and gradient.
    2. Ballast.
    3. Labor (native or foreign).
(e) Character and quantity of traffic.
(f) Length of time of experiment or application.

What character of work was covered?

What results were observed?

(a) The nature of relative expense for various classes of work done.
(b) In obtaining more prompt action in repair work.

Kindly give a statement descriptive of the methods of applying the practice, preparation therefor, method of supervising, etc., as well as any other information of interest.

In this circular opinions were also requested upon the general proposition, and a summary of the replies is attached hereto, marked Exhibit "A."

In addition to the information furnished by replies, one of the members, Mr. E. T. Howson, has personally canvassed a number of roads, which have shown interest in this proposition, and has prepared an article descriptive of the results obtained (see Exhibit "B").

Only three railroads have made a real test of the idea. Some others have tried it to a limited extent, but so far it has had very little trial.

The results obtained by the three roads which have made an application of the idea vary considerably, but it will be noted that in the case of the road which found the trial unsatisfactory, the test was started with apparently little preparation and did not extend over a long enough time to really demonstrate it.

The idea is purely an economic one, its purpose being to eliminate the wasteful expenditure due to men traveling long distances to do work, which, while possibly falling under the direction of men specially skilled, yet not beyond the power of an intelligent man of most any experience with ordinary tools.

The idea does not involve an immediate change to the condition where the Section Foreman will be charged with the entire duties of a branch of service, such as suggested, but, if practicable at all, must be started in a very limited way and developed gradually.

Some of the replies state this suggestion calls for a higher class of man—a much broader scope of education, and the class of man now generally found for Section Foreman is not capable of the enlarged service.

A number of the replies indicate that the idea is entirely practicable and can be worked out to advantage.

The thought may lead to a great change in organization whereby the Track Foreman may become extinct and in his place may appear a Roadway Foreman in charge of track, bridges, ordinary rough building work, ordinary water service, ordinary signal repairs, etc.

It is not known to what extent the idea is possible of development, but it warrants careful consideration.

Your Committee recommends continuing the study of the results to be obtained by the roads engaged in the experiment, and that it warrants very careful consideration and experiment by members of the Track Committee.

SUBJECT II—EQUATING TRACK VALUES.

The Sub-Committee in the first consideration of this subject came to the conclusion that in the absence of any information upon the subject, the basis of the study would have to be a series of experiments. Inquiry developed that while a very few roads had tried to work out a plan for equating values, it was in a very general way.

One exception to the rule was found in the case of the Baltimore & Ohio Railroad, which has developed a very complete and elaborate unit

of work system which has been quite successfully tried, and the thanks of the Sub-Committee are due that road, through Mr. Earl Stimson, for the thorough explanation of it which he made to the Sub-Committee at the Baltimore meeting.

The factors entering into this problem are very numerous and consist of generally:

Character of traffic.
Quantity of traffic.
Character of rolling stock.
Speed of trains.
Character of rail.
Character of ballast.
Character of roadbed.
Alinement.
Number of switches.
Number of feet of sidetrack.
Climatic conditions, etc.

These factors vary more or less between different parts of the country, and it is very doubtful if any results can be worked out which could be accepted everywhere, and in all probability it will always have to be a more or less local proposition, but the Committee feels that a general and thorough test should be made and has tried to work out a plan for that purpose.

This plan contemplates the selection of test sections of track and a thorough statement made of the physical characteristics, so that a proper relation can be established, and the members of the Track Committee were communicated with on August 19th last, as follows:

"The Sub-Committee on the Economics of Track Labor have taken up for study the matter of equated track values. The object of this study is to arrive at a basis for equating track values for determining the following things:

"(1) To arrive at proper units of cost of the various features which enter into track labor expense.

"(2) To arrive at a basis for equitably apportioning appropriations for expenditure.

"(3) To obtain a systematic measure of efficiency of track foremen and men.

"The subject has been given some tentative study by a few roads and some interesting data has been developed, but, as far as can be determined, the results heretofore obtained have been somewhat general and form only a guide to the complete determination desired.

"The Committee feels that the method of attacking this question in order to get positive and accurate data is to conduct a series of tests, taking actual cost data of various pieces of track for given periods of time. This seems to be the only way to accomplish the desired results, because of the varying conditions met in all classes of track.

"This is readily seen because the following are the important and general factors which govern expense, and which differ so materially as between sections of the same road:

Main Track Factors.	Side and Yard Track Factors.
Ton miles.	Number of cars handled.
Character of freight traffic.	do
Character of passenger traffic.	do
Alinement.	
Grades.	
Speed (maximum).	
Character of rail and age.	
Character and quantity of ballast.	
Character and number of ties.	
Character and number of switches.	
Character of roadbed.	
Climatic conditions.	
Number and character of road crossings.	
Number and character of water stations.	
Station grounds.	
Railroad crossings.	
Area of right-of-way.	

"The starting point in the collection of cost data would seem to be a plan providing for careful records being kept in order to obtain reliable information, and for this purpose the Sub-Committee suggest that each member of the Track Committee put into effect a plan for keeping information concerning several sections of track for a period of, say, one year, exercising careful watchfulness over the distribution of time, and, after this information is obtained, it will be possible, we think, to assign equated values for such things as the number of units generally entering into track maintenance.

"There is attached to this letter a blank form giving the physical characteristics required in connection with such experiment, also a suggested form for keeping the records of distribution of labor expended in this experimental track.

"The Sub-Committee appreciates that it means some special care, possibly a slight additional expense, to keep these records, but it is felt that the expense would be justified by the result. However, before putting the suggested plan into effect, we could appreciate a thorough criticism of the attached circulars."

The test should extend over a period of one year, during which time a special distribution of all labor should be kept on a sheet marked Exhibit "C," specially designed to give information not provided by the Interstate Commerce Classification.

This test will require special supervision, but the results are deemed worthy of the cost.

The results to be obtained by this method will enable certain units to be determined which can be given a relative value, so that an equitable distribution of monies can be made as between sections of road upon a

mathematical basis. In other words, it is a step in the direction of putting this feature of track maintenance upon a scientific basis.

The Sub-Committee has proposed to conduct a series of experiments by its individual members.

Your Committee recommends the matter to be studied further, and especially recommends that all of the members of the Track Committee assist in conducting such tests.

REVISION OF MANUAL.

Your Committee has found an error in the Table of Theoretical and Practical Leads, in the dimensions for the No. 15 Turnout, which it wishes to correct by substituting the following corrected dimensions for those in the Manual:

CORRECTIONS TO TABLE OF THEORETICAL AND PRACTICAL SWITCH LEADS.

No. 15 Turnout.

			Manual.	Corrected.
Theoretical Leads.				
Col.	X.	R = Radius of Center Line	1744.38	1744.45
"	XI.	D = Degree of Lead Curve	3° 17′ 01″	3° 17′ 06″
"	XII.	Distance Point of Switch to Theoretical Point of Frog	133.02	130.50
"	XIII.	Closure Straight Rail	92.36	89.83
"	XIV.	Closure Curved Rail	92.46	89.94
Practical Leads.				
Col.	XV.	R_1 = Radius of Center Line	1744.38	1743.80
"	XVI.	D_1 = Degree of Curve	3° 17′ 01″	3° 17′ 10″
"	XVIII.	Rectangular Co-ordinate X_1	77.95	77.98
"	XIX.	Rectangular Co-ordinate X_2	100.41	100.45
"	XXII.	Rectangular Co-ordinate Y_2	2.85	2.84
"	XXIII.	T = Tangent Adjacent to Switch Rail	0.00	0.09
"	XXV.	L_1 = Distance Actual Point of Switch to Theoretical Point of Frog	132.66	130.56
"	XXVI.	Lead = Distance Actual Point of Switch to Actual Point of Frog	133.28	131.19
"	XXVII.	Closure for Straight Rail	2-33 1-25.9	2-30 1-29.89
"	XXVIII.	Closure for Curved Rail	2-33 1-26	3-30

CONCLUSIONS.

Your Committee recommends for adoption and publication in the Manual:

(1) Typical plans of Nos. 8, 11 and 16 crossovers, as representing good practice.

(2) The five diagrams of speeds of trains through curves and level turnouts.

(3) The following table, showing relative speeds through le turnouts, to give the equivalent riding condition to track elevated th inches less than theoretically required:

Turnout		Speed
Frog Number	Length of Switch	Miles per Hour
4	11	9
5	11	12
6	11	13
7	16.5	17
8-10	16.5	20
11-14	22	27
15	33	37
16-24	33	40

(4) The corrections to Table of Theoretical and Practical Swit Leads recommended under "Revision of Manual."

Your Committee recommends receiving as information:

(1) Typical plans of Nos. 8, 11 and 16 double-slip crossings.

(2) Cleveland, Cincinnati, Chicago & St. Louis plan of standard N 8 double-slip switch.

(3) The report on "Speeds of Trains on Curves and Turnouts."

Your Committee recommends receiving as a progress report, the r port on Economics of Track Labor.

Your Committee recommends recommittal for further study:

(1) Typical plans for double-slip crossings, double crossovers a guard rails.

(2) Relation between worn flanges and worn switch-points.

(3) Economics of Track Labor.

Respectfully submitted,

COMMITTEE ON TRACK.

TYPICAL PLANS OF
NOS. 8, 11 AND 16
DOUBLE SLIP CROSSINGS.

TYPICAL PLANS OF
NOS. 8, 11 AND 16 CROSSOVERS.

EXHIBIT C.

SPECIAL RECORD TRACK SECTION —EQUATED MILEAGE TRACK SECTION.

Exhibit "A."

Road	Trial	Result	Opinion as to Practicability
Great Northern	Yes-limited.		That the practice should result in economy.
Illinois Central	Yes-50 miles.	Fair only.	Experiment not satisfactory but to be extended.
St. Louis & San Francisco	No.	None.	Doubtful.
Queen & Crescent	No.	None.	Doubtful; class of labor not suitable.
Detroit, Toledo & Ironton	Yes-limited.	Favorable.	Favorable.
Pennsylvania Lines	No.	None.	Doubtful.
Washington Terminal	No.	None.	Not applicable to a Terminal Co.
St. Louis Southwestern	No.	None.	Not favorable.
Chicago & Northwestern	No.	None.	Not favorable.
Mobile & Ohio	No.	None.	No opinion.
International & Great Northern.	No.	None.	Not favorable.
Northern Pacific	No-Rough Carpentry.	No reply.	No opinion; apparently favorable.
Minneapolis & St. Louis	No.	None.	Favorable.
Delaware, Lackawanna & Western	No-Bonding rails.	Not satisfactory.	Not favorable.
Terminal Railroad of St. Louis	No.	None.	Not applicable to Terminal.
Bangor & Aroostook	No.	None.	Not favorable.
Seaboard Air Line	No.	None.	No opinion.
New York Central & Hudson River	No.	None.	Not favorable.
Chicago & Alton	Yes-Signals.	Not satisfactory.	Not favorable.
Delaware & Hudson	No.	None.	No opinion.
Colorado & Southern	No.	None.	Recommended.
Lehigh Valley	No.	None.	No opinion.
Boston & Maine	No.	None.	Favorable.
Chicago Junction	No.	None.	Not practicable (Terminal)
Big Four	No.	None.	No opinion.
Missouri Pacific	No.	None.	No opinion.
Norfolk & Western	No.	None.	Not favorable.
Delaware & Hudson	No.	None.	Not favorable.
Erie	No.	None.	No opinion.
New York, New Havn & Hartford	No.	None.	No opinion.
Chicago & Eastern Illinois	No.	None.	No opinion.
Denver & Rio Grande	No.	None.	No opinion.
Missouri, Kansas & Texas	No.	None.	No opinion.
Carolina, Clinchfield & Ohio	No.	None.	No opinion.
Southern	No.	None.	No opinion.
Wheeling & Lake Erie	No.	None.	No opinion.
Richmond, Fredericksburg & Potomac	No.	None.	Favorable to limited extent.
El Paso & Southwestern	No.	None.	No opinion.
L. I. & L. A. Ry	No.	None.	Not favorable.
Nashville, Chattanooga & St. Louis	No.	None.	No opinion.
Duluth & Iron Range	No.	None.	Favorable.
Virginian	No.	None.	No opinion.
Philadelphia & Reading	No.	None.	Not applicable.
Pittsburgh & Lake Erie	No.	None.	Not favorable.
Lake Erie & Western	No.	None.	Favorable.
Central Railroad of New Jersey	No.	None.	Not applicable.
New York, Chicago & St. Louis.	No.	None.	No opinion.
Elgin, Joliet & Eastern	No.	None.	Favorable.
Buffalo, Rochester & Pittsburg	No.	None.	No opinion.
Chicago Great Western	No.	None.	Not favorable.
Louisville & Nashville	No.	None.	No opinion.
Santa Fe	No.	None.	No opinion.
Chicago, Milwaukee & St. Paul	No.	None.	No opinion.

Exhibit "B."

EXTENDING THE DUTIES OF SECTION FOREMEN.

The extent to which the duties of the Section Foreman can be broadened to include other simple work commonly handled by men of the bridge and building, water service, telegraph and signal departments, is a live question at the present time when the railroads are endeavoring to adopt every means to reduce the cost of operation. Briefly, the main advantage of consolidating these duties under the Section Foreman is that he is at all times on one section of limited mileage and can attend to any such work with the minimum delay and expense, as compared with sending a man from one of the other departments from the division headquarters. The principal objection made is the inability of the average foreman to perform such work at present. This plan has been tried to a limited extent with the consolidation of the track and carpentry, telegraph and water-service work, principally, however, on the smaller lines.

Although at first thought one would consider that the last two departments to be combined would be the track and signal departments, because of the generally considered technical details of signal maintenance, it is here that the combination has been most thoroughly tried and has made the most progress. While this has been to a certain extent the result of local conditions, careful consideration will show that there is at least one definite reason for this condition. The forces engaged in track and signal maintenance are most closely associated to-day, and it is here that there is the greatest overlap and friction. Representatives of both departments patrol the line daily and they must co-operate in making repairs of any magnitude to signals. Because of this interdependence there is certain to be more or less loss in efficiency.

The first extensive trial of the combination of track and signal maintenance under the supervision of one force was inaugurated on the Union Pacific. In April, 1910, that portion of the Union Pacific main line from Kearney, Neb., west 95 miles to North Platte, was equipped for this experiment. This portion of the line is double track, equipped with Union Switch & Signal Company Style "B" automatic signals, and has an average train movement of 28 passenger and 20 freight trains daily. Previous to 1910 there were 24 Section Foremen at $65 per month each, and seven signal maintainers were employed at $75 per month. In combining these forces the District Supervisor of Signals was made Assistant Roadmaster, and this 95 miles of line was divided into 11 sections, each in charge of a foreman at $75 and an assistant foreman at $65. Each gang was provided with a gasoline motor car and with a handpower velocipede, making the customary track inspection and taking care of the signals. This man also tightens bolts and does other work customarily required of the track walker.

This same plan of organization was extended over the double-track main line of the Union Pacific, from North Platte west 135 miles to Sidney in April, 1912, and from the west limit of the Omaha terminals west to Columbus, about 85 miles, on May 1, 1913. On August 1 of this year the maintenance of the Omaha terminals was also placed under this same system, while it is planned to further extend it over the two remaining districts of the Nebraska division, between Omaha and Cheyenne, Wyo., next spring. Thus the signals and track are now maintained by one common force on 351 miles out of a total of 516 miles of main line on the Nebraska division of the Union Pacific.

While the actual economies resulting from this system cannot be definitely ascertained because of the fact that these districts have been equipped with motor cars and the length of sections has been increased, it is felt by those in charge that the combination of track and signal maintenance has contributed its share to the large total savings which have been made. The work, formerly requiring seven signal maintainers at $75 each on the original district of 95 miles and a track walker on each section, has been consolidated under nine assistant foremen at $65 each. While the Nebraska division used to be the highest in point of expenditures per mile for maintenance, it has gradually fallen until it is now the lowest on the Union Pacific, with the single exception of the Colorado division, which consists largely of branch lines. This is in spite of the fact that the main line is double track and handles the heaviest traffic of any division on the system. With this arrangement the friction between the signal and track departments has been eliminated, insulated joint failures have largely disappeared and the avoidable signal failures have decreased materially.

The Illinois Central was the second road to combine the track and signal maintenance experimentally on 41 miles of double-track main line from Ballard Junction, near the south end of the Cairo bridge, to Fulton, Ky., on October 1, 1912. The sections on this district average four miles in length, and the line is equipped with Hall normal danger gas signals spaced 1½ to 2 miles apart. Previous to the inauguration of this plan the Assistant Signal Engineer spent three weeks instructing the Section Foremen in their duties, and the Division Supervisor also spent as much time as he could spare from his other work in training the foremen. At the time this plan was put into operation the salary of the foremen was increased $5 per month and white assistant foremen were employed, the laborers being colored. No increase was made in the length of the sections.

When the signals were turned over to the track forces the number of failures increased greatly. A General Foreman was, therefore, employed in September to give his entire attention to the further instruction of the foremen on this district, and since that time the failures have been greatly reduced, although they are still considerably above normal. Also the cost of maintenance of the track and signals is now in excess of that under the old system. However, the experiment on this road has been

under way too short a time to enable the officers to draw any definite conclusions, but it is believed that both the cost of maintenance and the number of failures will compare favorably with results obtained under former methods.

The Chicago & Alton is the most recent road to combine the track and signal forces experimentally. About the middle of April of this year these forces were combined on 30 miles of the double-track main line between Bloomington, Ill., and Ocoya. These tracks were laid with 80-lb. and 90-lb. rail with rock ballast and were equipped with Hall signals. Previous to the combination of these forces the track was maintained with section gangs covering an average of four miles of line, under the direction of a foreman at $60 per month, and the signals by a maintainer covering 15 miles of line and paid $75 per month, with a lamp tender at $40 per month. In combining these forces the maintainer was dispensed with and the foreman's wages increased to $70 per month. The length of section remained the same and no assistant foreman was provided. After a trial of about three months this plan was decided a failure, and the maintenance of track and signals was placed on the original basis. It was found that the foremen were devoting an excessive amount of time to the maintenance of signals in their desire to hold the number of failures down to normal, and thus retain their increase in salary. As a result their efficiency in the track work decreased, while the number of signal failures increased, due to the inexperience of the foremen.

The contrast between the results obtained on these three roads is instructive and can be studied with value. The success or failure can be attributed largely to the nature and extent of the preparatory education and training of the foremen in their new duties and to the degree of patient assistance shown by the officers in its development. The Union Pacific found, as did the Illinois Central and the Alton, that the number of signal failures increased at first, as would naturally be expected when their maintenance was turned over to partially experienced men. The Alton's experiment did not continue sufficiently long to overcome this initial period of increased signal failures, and if it had been continued for six months longer these failures would probably have approached a normal condition as they have done on the Union Pacific and are now doing on the Illinois Central. In fact, on the Union Pacific the average number of failures is now reported to be lower than on the old system.

The degree of success attained by this method on the three roads corresponds largely to the extent of the education of the foremen. On the Union Pacific the men had access to the courses of instruction of the Educational Bureau on maintenance of signals for several months before the signals were turned over to them, and they had availed themselves very generally of the opportunity of studying the elementary details of signal maintenance. Also, this plan was in contemplation on the various sub-divisions for some time before its installation, and opportunity was thus given to coach the men in their new duties. After the adoption of this plan on the first sub-division, several men experienced in the main-

tenance of signals were transferred from this sub-division to the other sub-divisions as assistant foremen when the joint maintenance was put in effect there to aid in the new work.

While the Assistant Signal Engineer of the Illinois Central devoted three weeks to instructing the Section Foremen on this line regarding their new duties, the officers now realize that this was insufficient in view of the fact that the Division Supervisor of Signals could devote only a limited amount of attention to the men after this system was inaugurated. This defect has been remedied to a large degree by the employment of a General Foreman, who is spending his entire time on this territory, and a marked improvement has been noted.

While some preparation was made on the Alton, the plan was decided on quickly, and the men were given only a couple of weeks' instruction in connection with their other work. The foremen were not provided with assistant foremen and the responsibility for the maintenance of signals fell upon them in addition to their regular track work. It is difficult to see how men thrown upon their own resources, after this limited amount of instruction, could equal experienced maintainers in performing that work.

In view of the limited extent to which this experiment has been tried, no definite conclusions can be drawn at this time, and the entire subject is still in the experimental stage. At the same time, this method would appear to offer possibilities for economy in maintenance and deserves the careful consideration by railway officers not only in combining the maintenance of the track and signals, but more particularly the combination with light carpentry and similar work. An incidental advantage, which should not be lost sight of, is the possibility of attracting a better class of men from the signal, bridge and other departments because of the increased salary paid for the enlarged duties.

Exhibit "D."

STATEMENT OF CHARACTERISTICS OF SPECIAL RECORD TRACK SECTIONS.

1. Railroad ....
2. Division ....
3. District ....
4. Station ....
5. Mile post........................to mile post..................
6. Double or single track..
7. Main or branch line..
8. Rail:
   (a) Weight and section......................................
   (b) Condition per cent. life spent............................
9. Ballast:
   (a) Character ....
   (b) Condition ....
   (c) Depth under ties..
10. Number of ties per mile..
    (a) Size ....
    (b) Treated or untreated......................................
    (c) Kind treatment ....
11. Per cent. track anchored..
12. Per cent. track tie plated..
13. Number of miles of main track: First..............................
    Second ....
    Third ....
    Fourth ....
14. Number of miles of passing track..................................
    Yard leads ....
    Other yard tracks..
    Industrial tracks ....
15. Character and condition of rail:
    (a) Passing track ....
    (b) Yard leads ....
    (c) Other yard track..
    (d) Industrial tracks ....
16. Character and condition of ballast sidetracks:........................
17. Alinement
    - Number of feet of curve..
    - Of each degree..
    - Number of feet of straight track................................
    - Degree curvature per mile..

17A. Miles of grade of less than 0.6 per cent..........................
Average rate of such grade..........................
Miles of grade of 0.6 per cent. and over..........................
Average rate of such grades..........................
18. Number of miles of embankment..........................
19. Number of miles of excavation..........................
20. Character of roadbed..........................
21. Character of drainage..........................
22. Estimated ton miles per year:
(a) First track..........................
(b) Second track..........................
(c) Third track..........................
(d) Fourth track..........................
23. Number of high-speed trains per year, freight..........................
Average speed of high-speed freight trains..........................
24. Number of high-speed trains per year, passenger..........................
Average speed of high-speed passenger trains..........................
25. Area and character of right-of-way..........................
26. Area of station grounds..........................
27. Number of railroad crossings (main)..........................
Number of railroad crossings (side)..........................
Number of street crossings (main)..........................
Number of street crossings (side)..........................
Number of highway crossings (main)..........................
Number of highway crossings (side)..........................
28. Number of interlocking plants..........................
Signal characteristics..........................
29. Number of main line switches:
(a) Hand operated..........................
(b) Interlocker..........................
30. Number of side track switches:
(a) Hand operated..........................
(b) Interlocker..........................
31. Number yard switches..........................
32. Number industrial switches..........................
33. Track pans, feet of track..........................
34. Number of bridge approaches..........................
35. Linear feet of bridges:
(a) Open deck..........................
(b) Ballast deck..........................
(c) Steel bridges..........................
36. Mean January temperature..........................
37. Mean July temperature..........................
38. Number of thaws during winter..........................
39. Annual precipitation (rain and snow)..........................
40. Winter snowfall..........................

Exhibit "E."

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 7 Crossing—Frog Angle 8°10'16"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Elliot Frog & Switch Co		15'0"	Cvd.		11'0"		3'0"	Rail		48'7½"	4½"
Lorain Steel Co	8'11¼"	15'0"	Cvd.	18'2 7/16"	Rigid Frog					48'2 7/16"	4½"
The Weir Frog Co	10'9½"	15'0"	Cvd.	15'1"	10' 0"	15'2"	4'0"	Rail	18"	45'1"	4½"
Great Northern	*9'11"	15'0"	Cvd.	16'3⅜"	7'10"	16'4"	5'9"	Rail	17"	46'3⅜"	5"
Pennsylvania Lines West of Pittsburgh	9' ½"	18'0"	Cvd.	12'3 11/16"	11'0"		3'0"	Rail		48'3 11/16"	4½"
Pittsburgh & Lake Erie		15'0"		18'6"	Rigid frog					48'6"	
American Frog & Switch Co	9'7½"	15'0"	Cvd.	17'4½"	10'0"	17'6"	4'0"	Rail	16"	47'5"	4½"

*Theoretical point.

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 8 Crossing—Frog Angle 7°09′10″—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
American Frog and Switch Co.	10′11⅛″	15′0″	Cvd.	24′ 2″	10′0″	24′ 3″	4′0″	Rail	16″	54′ 2″	4½″
Cleveland Frog & Crossing Co.		16′6″	Cvd.	21′ 0″	12′0″	21′ 0″	4′6″	Rail		54′ 0″	4½″
Elliot Frog & Switch Co.		15′0″	St.	22′11″	11′0″	22′11¾″	6′0″	Rail		52′10¾″	4½″
Lorain Steel Co.											
Wm. Wharton, Jr., & Co.	9′ 8½″	15′0″	St.	26′ 7 1/16″	15′0″	26′ 8½″	5′8″	Special Manganese		56′ 7 1/16″	4″
The Weir Frog Co.	12′ 4″	15′0″	Cvd.	21′ 5¼″	10′0″	21′ 6½″	4′0″	Special Manganese	18″	51′ 5¾″	5″
Baltimore & Ohio	11′ 7¾″	16′6″	St.	19′10¼″	11′0″	19′11½″	4′0″	Rail		52′10¼″	4½″
Baltimore & Ohio	11′ 8¾″	16′6″	St.	19′ 8¾″	11′0″	19′ 9½″	4′0″	Rail		52′ 8¼″	4½″
Chicago & Northwestern	11′ 1¾″	15′0″	Cvd.		12′0″	23′±	6′0″	Rail		53′10¾″	
Cleveland, Cincinnati, Chicago & St. Louis		16′6″	Cvd.	23′ 0″	12′0″	6′ 8″	Spcl.Mang			56′ 0″	4½″
Chicago, Rock Island & Pacific		16′6″		20′ 7½″	10′0″		None	Rail		53′ 7½″	
Central Railroad of New Jersey	9′ 8½″	15′0″	10′ St. 5′ Cvd.	26′ 9 21/32″	15′0″	26′10⅞″	5′8″	Rail or Man. rein.	14″	56′ 9 21/32″	4″
Great Northern											
Kansas City Terminal		15′0″	Cvd.	20′ 7½″	10′0″		Spcl.Mang		18 13/16″	50′ 7½″	4½″
Lehigh Valley	10′ 4″	15′0″	St.	25′ 7½″	12′6″	25′ 7¾″	6′0″	Rail		55′ 7½″	4″
New York Central & Hudson River		15′0″		29′ 5⅞″	10′0″	17′ 6½″	6′0″	Rail		59′ 5¾″	4″
New York, New Haven & Hartford	9′10″	15′0″	Cvd.		10′0″		6′0″				
New York, Chicago & St. Louis		15′0″		23′ 6″	11′0″	23′ 6″	None	Rail		53′ 6″	4½″
Pennsylvania	10′ 4″	15′0″	Cvd.	25′ 5¾″	12′4½″	25′ 7″	5′6″	Rolled Manganese	15″	55′ 5¾″	4″
Philadelphia & Reading	9′ 7 3/16″	15′0″	Cvd.	26′ 8¼″	15′0⅝″	26′ 9½″	5′8″	Rail	14″	56′ 8½″	
Suggested	10′ 4″	16′6″	Cvd.	22′ 6 9/16″	10′0″	22′ 7½″	6′0″	Rail	14⅞″	55′ 6 9/16″	4″

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 9 Crossing—Frog Angle 6°21'35"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Central Railroad of New Jersey	10'11 1/16"	15'0"	10' St. 5' Cvd.	33'10 1/16"	15'0"	23'6⅝"	5'8"	Rail or Man. rein.	14"	63'10 5/16"	4"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 10 Crossing—Frog Angle 5°43'29"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Cleveland Frog & Crossing Co.		18'0"	St.	33' 0"	15'0"	Spcl. Mang				69'0"	4½"
Baltimore & Ohio	15' 6¼"	16'6"	St.	31' 0"	15'0"	31' 1¾"	6'0"	Rail		64' 1"	4½"
Central Railroad of New Jersey	12' 1⅝"	20'0"	13' St. 7' Cvd.	30'11⅜"	15'1½"	31'0¼"	5'8"	Rail	14"	70'11⅜"	4"
Chicago & Northwestern	12' 2"	20'0"	Cvd.		14'8"	30'±	9'0"	Rail		69'11½"	
Kansas City Terminal		15'0"	Cvd.	29' 9½"	14'6"	Spcl.			20¾"	59' 9½"	5"
Lehigh Valley	12'11"	15'0"	St.	39' 3"	15'0"	30'0"	6'0"	Rail		69' 3"	4"
New York Central & Hudson River		15'0"		38' 0"	15'0"	15'0"	11'6¼"	Rail		67'11½"	4"
Pennsylvania	12'11"	18'6"	Cvd.	32' 3"	15'9"	32'4"	5'6"	Rolled Manganese	15"	69' 3⅝"	4"
Pennsylvania Lines West of Pittsburgh	13' 2¾"	18'0"	St.	33' 0"	15'0"		3'0"	Rolled Manganese		69' 0"	4½"
American Frog & Switch Co.	13' 9"	18'0"	Cvd.	31' 7⅝"	15'0"	31'8⅜"	6'0"	Rolled Manganese	16"	67' 7⅜"	4½"
Philadelphia & Reading	12' 0⅞"	20'0"	Cvd.	30'11¼"	16'6"	31'0"	5'8"	Mang.	13⅞"	70'10⅜"	4"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 11 Crossing—Frog Angle 5°12'18"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Suggested	13'6"	22'0"	St. or Cvd	33'8"	12'5¾"	15'0"	6'0"	Rail	14¼"	77'8"	4"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 12 Crossing—Frog Angle 4°46'19"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Cleveland Frog & Crossing Co.		22'0"	St.	33'0"	18'0"		Spcl.Mang			77'0"	5"
Kansas City Terminal		20,0"	Cvd.	30'9⅝"	15'±		Spcl.Mang		21½"	70'9⅝"	4½"
Lehigh Valley	15'6"	15'0"		53'2⅝"	15'0"	26'0"	6'0"	Rail		83'2⅝"	4"
American Frog & Switch Co.	16'6"	20'0"	Cvd.	41'1⅛"	15'0"	15'0"	6'0"	Rail	16"	81'1⅛"	4½"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 14 Crossing—Frog Angle 4°05'27"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Chicago & Northwestern	17'11⅛"	20'0"	St.		15'0"	20'0"	None	Rail		97'5½"	

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 15 Crossing—Frog Angle 3°49'06"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Cleveland Frog & Crossing Co		30'0"	St.	44'8"	15' 0"	Spcl. Mang				104' 8"	4½"
Indianapolis Switch & Frog Co	19'0"	30'0"	St.	44'4"	18' 0"	23'9¼"		Rail	14½"	104' 4"	4½"
Wm. Wharton, Jr., & Co		30'0"	St.	44'8¼"	9' 1"	Spcl. Mang		Rail		104' 8¼"	4½"
Central Railroad of New Jersey	18'4⅜"	20'0"	St.	66'0"	16' 2"	33'0"	5'8"	Rail or Man. rein.	14⅛"	106' 0"	4"
Lehigh Valley	20'7½"	15'0"	St.	71'4½"	15' 0"	30'0"	6'0"	Rail		101'4½"	4"
Pennsylvania	19'4¼"	28'0"	Cvd.	47'9¾"	8'7⅝"	33'0"	6'0"	Rolled Manganese	15"	103'10"	4"
Pennsylvania Lines West of Pittsburgh	19'1"	30'0"	St	44'8"	15'0"		3'0"	Rail		104' 8"	4½"
Philadelphia & Reading	18'1⅜"	30'0"	St.	46'6"	22'11⅛"	33'0"	5'8"	Manganese	13"	106' 6¼"	4"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 16 Crossing—Frog Angle 3°34'47"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Cleveland Frog & Crossing Co		25'0"		50'0"	12'0"	Spcl. Mang				100'0"	4½"
Suggested	19'6"	33'0"	St.	47'1½"	14'0$\frac{1}{16}$"	20'0"	8'0"	Rail	14⅛"	113'1⅛"	4"

TABLE OF DIMENSIONS OF DOUBLE SLIP CROSSINGS

Number 20 Crossing—Frog Angle 2°51'51"—Movable Points

Plan Furnished by	Distance Frog to Switch	Length of Points	Inside Points Straight or Curved	Length of Middle Rail	Length of Movable Points	Length of Knuckle Rail	Length of Easer Rail	Constn. of Knuckle	Gage to Gage at Points	Length over Points	Throw.
Pennsylvania	25'10"	30'0"	Cvd.	78'4½"	11'9⅜"	24'5"	9'0"	Rolled Manganese	15"	138'4¾"	4"

REPORT OF COMMITTEE XVI—ON ELECTRICITY.

GEORGE W. KITTREDGE, *Chairman;*
D. J. BRUMLEY,
R. D. COOMBS,
A. O. CUNNINGHAM,
WALT DENNIS,
L. C. FRITCH,
GEORGE GIBBS,
G. A. HARWOOD,
E. B. KATTE,
C. E. LINDSAY,
W. S. MURRAY,
J. B. AUSTIN, JR., *Vice-Chairman;*
J. A. PEABODY,
FRANK RHEA,
J. W. REID,
A. F. ROBINSON,
J. R. SAVAGE,
A. G. SHAVER,
MARTIN SCHREIBER,
W. I. TRENCH,
H. U. WALLACE,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee presents herewith its annual report for the year 1913.

No meetings have been held by the full Committee during the year, the work having been done by correspondence and by Sub-Committees.

Sub-Committees for the year were appointed as follows:

Sub-Committee No. 1—Clearances:

G. A. Harwood, Chairman;
A. O. Cunningham,
L. C. Fritch,
G. Gibbs,
E. B. Katte,
W. S. Murray,
J. A. Peabody,
A. G. Shaver.

Sub-Committee No. 2—Transmission Lines and Crossings:

R. D. Coombs, Chairman;
D. J. Brumley,
A. O. Cunningham,
G. A. Harwood,
W. S. Murray,
F. Rhea,
J. R. Savage,
J. M. Reid,
A. F. Robinson.

Sub-Committee No. 3—Insulation:

W. S. Murray, Chairman;
R. D. Coombs,
G. Gibbs,
E. B. Katte,
F. Rhea,
M. Schreiber,
H. U. Wallace.

Sub-Committee No. 4—Maintenance Organization:
J. B. Austin, Jr., Chairman;
L. C. Fritch,
C. E. Lindsay,
W. I. Trench,
J. R. Savage.

Sub-Committee No. 5—Electrolysis:
E. B. Katte, Chairman;
D. J. Brumley,
W. Dennis,
G. Gibbs,
M. Schreiber,
W. I. Trench,
H. U. Wallace.

Sub-Committee No. 6—Relation to Track Structures:
C. E. Lindsay, Chairman;
J. B. Austin, Jr.
L. C. Fritch,
J. R. Savage,
W. I. Trench.

(1) CLEARANCES.

The following report from the Sub-Committee on Clearances has been received:

(a) Data has been secured covering overhead clearances on electrified railroads and has been embodied in Table 2, pp. 616 and 617. The Committee expects to correct these statements annually for the records of the Association.

(b) The attached Diagram "B", showing Typical Overhead Clearance Diagrams for permanent way structures and working conductors, has been circulated amongst the members of this Sub-Committee and their approval of it has been secured. It will be noted that this diagram conforms generally to the practice indicated on the tabular statement referred to under (a).

The first four diagrams are taken from report prepared by the Committee on Electrical Workings of the American Railway Association, and are also being considered by a Sub-Committee of the American Electric Railway Association.

The fifth diagram has been added as in the judgment of this Sub-Committee it seemed that the overhead clearance necessary at various points on lines operated by d.c. rail should be indicated and this minimum under-clearance of structures has been based on the minimum permitted by the New York State Public Service Commission.

(c) In the report of this Sub-Committee for 1912 it was stated that information was not then sufficient to make recommendations on clearance lines for automatic stops. During the past year a meeting has been held at which representatives of the American Railway Association, American Electric Railway Association and the American Railway Engi-

neering Association were present, this Association having been represented by Messrs. Katte, Shaver and Trench and the chairman of the Sub-Committee. After discussion, the Joint Committee adopted the following resolutions:

"(1) Inasmuch as the present state of development of automatic train stops or speed regulation devices is in an experimental stage, and since no such device has as yet been generally adopted by steam railroads, this Joint Committee should give no further consideration at this time to the location of such devices on the track structure, and should so report back to their various associations.

"(2) It is recommended to the Clearance Committees of the various associations that further study be made of the Equipment Clearance line shown on the third-rail clearance diagram adopted by the American Railway Engineering Association at its meeting of March, 1912, between the point FE and the gage line of the nearest running rail and to the location of the third-rail clearance line between point ET and the gage line of the nearest running rail."

Following this meeting, data on Equipment Clearance Lines of various railroads has been collected. From the present information, it seems that the EE-FE line, indicated on approved diagram "A," of the American Railway Engineering Association, may be extended toward the gage line, and, if further study does not develop serious encroachment, the space below said extended line would be available for automatic stops or other structures of a similar nature. Your Sub-Committee proposes to continue this study in conjunction with the other associations.

(d) Table 1, page 1, covering data on third-rail clearances, has been corrected up for the year and is attached to this report.

(2) TRANSMISSION LINES AND CROSSINGS; (3) INSULATION; (4) MAINTENANCE ORGANIZATION; (6) RELATION TO TRACK STRUCTURES.

Your Committee has nothing to report on these four subjects, other than progress.

(5) ELECTROLYSIS.

The following report has been received from the Sub-Committee and is submitted herewith as one of progress and for the information of the Association:

"The work assigned to this Sub-Committee by the Executive Committee is as follows:

"(1) Report on the effect of electrolytic action on metallic structures and the best means of preventing it.

"(2) Continue the investigation of electrolysis and insulation.

"There has been no meeting of the Sub-Committee on Electrolysis pending the report of a special sub-committee appointed on May 12, consisting of Messrs. Katte and Brumley, for the purpose of representing the Committee on Electricity, as members to a National Committee on

Electrolysis, originated by the President of the American Institute of Electrical Engineers.

"The first and only meeting of the Joint National Committee on Electrolysis, thus far held, was convened in New York City on May 27, 1913, and owing to the importance of this meeting and the organizations there represented, we include in this report the full minutes of the meeting referred to, as follows:

"JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

"Minutes of Meeting Held in New York, May 27, 1913.

"A meeting of the Joint National Committee on Electrolysis was held in the offices of the American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York, on May 27, 1913.

"There were present: Messrs. R. P. Stevens, A. S. Richey, and Calvert Townley, representing the American Electric Railway Association; E. B. Katte, D. J. Brumley and W. I. Trench, representing the American Railway Engineering Association; H. S. Warren and E. L. Rhodes, representing the American Telephone & Telegraph Company; Philip Torchio, L. L. Elden and D. W. Roper, representing the National Electric Light Association; B. J. Arnold, F. N. Waterman and Ralph D. Mershon, representing the American Institute of Electrical Engineers.

"Mr. Mershon stated that as President of the American Institute of Electrical Engineers, he felt it his duty to call the meeting to order and turn it over to a chairman to be elected by the Committee. He then set forth the object of the meeting and stated that the associations who had not yet appointed representatives had been conferred with by letter on March 12, and that the American Water Works Association had replied to the effect that it would not be possible for the Association to take any action until its convention, which would be held on June 23. The Natural Gas Association of America has also replied, stating that no action could be taken by that association until after their convention on May 20. The American Gas Institute had not yet replied to Mr. Mershon's communication.

"Mr. Torchio suggested that inasmuch as all of the associations who had been invited had not yet appointed representatives, it might be inadvisable to take any definite action until after the representatives of these associations had been appointed; these associations are: the American Gas Institute, the American Water Works Association, and the Natural Gas Association of America. Mr. Torchio further suggested that a temporary chairman be appointed pending the appointing of these representatives. This view prevailed and Mr. B. J. Arnold was elected temporary chairman.

"Mr. Townley was asked to give his views as to what work should be undertaken by the Committee, and he set forth to some extent the field that, in his opinion, the Committee's work should cover, which was that it should be mainly suggestive and constructive and that the Committee should recommend to the associations interested certain findings which, when adopted, could be utilized by the associations in their work with each other in the handling of the general subject of electrolysis.

"There being a large representation of the Committee present, it was deemed best to proceed with a general discussion of the subject, in order that time might not be lost, keeping in view, however, the fact that no definite action of any character would be taken until the other representa-

"At the suggestion of Mr. Waterman, who stated that he had had some communication with the representatives of the American Gas Institute, it was thought best to appoint a Committee to confer with the three associations who have not yet appointed representatives, with a view to obtaining their co-operation.

"Upon motion of Mr. Torchio, seconded by Mr. Katte, the temporary chairman was requested to act as such Committee.

"Upon motion of Mr. Waterman, it was voted after some discussion to invite the National Bureau of Standards to appoint representatives on the Committee.

"A general discussion then followed as to the object, work and scope of the Committee, in which several members took part. At the close of the discussion the following resolution was offered by Mr. Waterman, seconded by Professor Richey, and carried:

"*Resolved,* That the chairman be authorized to appoint a Committee on Scope, Organization and Plan of Work, such Committee to include representatives of each of the associations interested, and that no further attempt at work be made by the Joint Committee until the Committee on Scope, Organization and Plan of Work can tender a report to the Joint Committee, outlining the scope of its work and suggesting a plan of procedure.

"The chairman appointed Messrs. Calvert Townley, Chairman; F. N. Waterman, E. B. Katte and H. S. Warren.

"Mr. Katte stated on behalf of the American Railway Engineering Association, of which he is a representative, that the principal desire of that Association, as regards lectrolysis, is for education; that a Sub-Committee on Electrolysis of that Association had spent most of its time during the past year and a half in preparing an educational thesis, in very elementary language, which when presented in the report of the Committee at the last annual meeting appeared to be just along the lines of information that some railway men were looking for; and that the Sub-Committee had been instructed to continue its work along the same lines; so that the representatives of the American Railway Engineering Association will be glad to have information to present to the Association along educational lines.

"Mr. Waterman stated that he knew of a number of such reports as mentioned by Mr. Katte having been prepared, and that perhaps a committee representing the Joint Electrolysis Committee could be appointed to collect such reports and data as may be available, and select therefrom a list of matters as might be agreed upon as fundamental, which should form the basis of some sort of an educational document to be issued by the Committee; that this seemed to be a way in which the Committee could be of most use.

"The question then arose as to whether the Joint Committee should suspend its work pending the appointment of the representatives of the associations who had not taken action, and it was decided that the Committee would continue to hold meetings as occasion might require.

"The chairman then named the members of the Scope and Organization Committee, and suggested that the Committee prepare a skeleton outline of what it considered the Joint Committee should do, subject, of course, to the approval of the Joint Committee."

JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

(As constituted May 27, 1913.)

Societies.	*Representatives.*
American Electric Railway Association:	R. P. Stevens, Allentown, Pa. Calvert Townley, New York. Prof. A. S. Richey, Worcester, Mass.
American Railway Engineering Asosciation:	E. B. Katte, New York. D. J. Brumley, Chicago, Ill. W. I. Trench, Baltimore, Md.
American Telephone & Telegraph Co.:	H. S. Warren, New York. F. L. Rhodes, New York.
National Electric Light Association:	Philip Torchio, New York. L. L. Elden, Boston, Mass. D. W. Roper, Chicago, Ill.
American Institute of Electrical Engineers:	B. J. Arnold, Chicago, Ill. F. N. Waterman, New York. Paul Winsor, Boston, Mass.
American Gas Institute:	Not yet appointed.
American Water Works Assn.:	Not yet appointed.
Natural Gas Assn. of America:	Not yet appointed.

"The useful work of the Joint National Committee on Electrolysis is therefore at the present time held up pending appointment of delegates from the American Gas Institute, the American Water Works Association and the Natural Gas Association of America.

"Your Sub-Committee on Electrolysis has deemed it inadvisable to make any further report pending some definite action of the Joint National Committee."

TABLE 1—DATA REGARDING THIRD RAIL CLEARANCES.

Revised to December 16, 1913.

Name of Company	Plan No.	Top or Under Contact	Protected	Uses Steam Equipment	Structures Clear Prop. Lines	Mileage in Operation	Mileage Planned for Immediate Future	Mileage Using Steam Equipment	Remarks.
Albany Southern	1	Top	No	Yes	Yes	65.00		65.00	
Aurora, Elgin & Chicago	2	"	"	"	No	95.00	None	95.00	7.70 miles O. H. trolley
Baltimore & Ohio	3	"	Partly	"	Slight	7.00	None	7.00	Elect. operation for up-grades only
Boston Elevated Ry	4	"	No	No	No	26.587	6.00	None	
Brooklyn Rapid Transit	5	"	"	"	"	88.636	Consid'able	None	49.83 miles O. H. trolley
Central California Traction	7	Under	Yes	For Emergency only	Yes	48.00	None	70.00	27 mi. O. H. trolley inc. in 70 miles
Detroit River Tunnel Co.	26	"	"	Yes	"	19.27		19.27	New station will require add. 3d rail
Grand Rapids, Grand Haven & Muskegon	8	Top	No	No	No	45.00	None	None	10 miles O. H. trolley—Urban
Hudson & Manhattan	9	"	Yes	"	"	20.00	None	None	Subway
Interborough Rapid Transit	10-11-12	"	"	"	"	203.34	172.66	None	Elevated 118.0, Subway 85.36
Lackawanna & Wyoming Valley	14	"	No	Yes	"	43.00	None	43.00	5 miles O. H. trolley
Long Island	13-18	"	Yes	"	Yes	203.34	None	203.34	
Metropolitan West Side, Chicago	6	"	No	No	No	51.08			Elevated
Michigan United	16	"	"	"	"	104.60	None	None	
Northwestern Elevated, Chicago	6	"	"	"	"	60.00		10.00	16 miles O. H. sliding contact
Northern Elec. Ry., Chico, Cal.	17	"	"	For Emergency only	"	141.00	14.00	None	18.79 mi. O. H. trolley and pantagraph
New York State Railways	25	Under	Yes	Yes		105.56	None	98.62	8.95 miles O. H. trolley
N. Y. C. & H. R.	26	"	"	"	Yes	294.88		284.38	2.67 miles O. H. conductors
Penna., Manhattan Div.	18	Top	"	No	"	70.93		None	1.63 mi. O. H. contact included in total
Penna., New York Div.		"	"	Yes	"	15.90		13.00	
Penna., West Jersey & Seashore	23	"	"	"	"	150.26		150.26	8.65 mi. O. H. trolley included in total
Pennsylvania							111.5		Philadelphia and vicinity
Puget Sound Electric Ry.	19	"	No	No	No	30.00		None	10.0 mi. O. H. trolley—Urban
Philadelphia & Western	20	"	Yes	"	"	34.60	None	None	1.50 mi. trolley in yards
Philadelphia Rapid Transit Co.		Under	"	"	"	18.61			Subway and Elevated Lines
Scioto Valley Traction Co.	21	Top	No	"	Yes	65.00		None	3.86 miles trolley—Urban
South Side Elevated, Chicago	6	"	"	"	No	36.05	None	None	0.6 mi. at yard leads
Wilkes-Barre & Hazelton	24	"	Yes	Yes	Slight	31.60	None	29.50	1.50 mi. O. H. trolley
						2011.943	304.16	1038.37	

TABLE 2.—DATA REGARDING OVERHEAD CLEARANCES.

Name of Company	Conductor	Height Above Rail	Elect. Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const. at Crossings Other Roads	Remarks
Bangor Ry. & Elect. Co.	2|0 8 & O	Max. 23'0" Std. 19'0" Min. 15'0"	63.0	None	None Submitted	D-C 600	Trolley		
Brooklyn Rapid Transit	4|0 Grooved	Std. 22'6" Min. 19'0"	80		Outline of Equipment	D-C 600	"	Catenary	Freight handled by electric locomotives.
Chicago & Milwaukee	3|0 Grooved	Max. 23'6" Std. 22'0" Min. 18'0"	173	None	Plan of Pole Line Const.	D-C 600	"	Stand. insulated trolley crossings	
Detroit United Ry.	2|0 & 3|0 All three Forms	22'6" 18'6" 14'0"	777.29	100.33	Stand Line Const.	D-C 600	"	Built according to Specs. of Michigan Ry. Commission.	
Fonda, Johnstown & Gloversville Ry.	4|0 Grooved	21'0" Steam Crs'gs 18'0" 15'0"	80	50	None Furnished	D-C 600	"	None	
Fort Dodge, Des Moines & Southern Ry.	3|0 & 4|0 Grooved	24'0" 22'6" 21'0"	150	150	None Furnished	D-C 1200	"	Guard wires	
Iowa & Illinois Ry.	4|0 Round	23'0" No Stand. in State 19'0"	38	36	Have none	D-C 600	"	Double spans, all poles heavy and back guy	
Niagara, St. Catharines & Ontario Ry.	4|0 Grooved	Std. 22'6" Min. 19'0"	80	80		D-C 600	"	None	
N. Y. N. H. & H. (N. Y. W. & B.)	4|0 8	23'0" 22'0" 18'0"	53	53	See Note	A-C 11,000	Pantagraph	Yes	Note—Diagram showing typical O.H. construction.
New York State Rys.	2|0–4|0 Round and Grooved	22'0" 18'0" 15'0"	240	None	Yes	D-C 575-625	Contact		
Oneida Ry. Co.	4|0 Round	22'0" 22'0" 22'0"	8.95	8.95	Diagram Submitted		Trolley	None	
Oregon Elec. Ry.	4|0 Grooved	23'0" 22'0" 16'0"	99.34	See Note	None Submitted	D-C 72m- 600 V. 27m-1300 V.	"	See print	During extensions steam used on all lines except 1.4 miles in city.

TABLE 2—Continued—DATA REGARDING OVERHEAD CLEARANCES

Name of Company	Conductor	Height Above Rail	Elect. Single Track	Steam Equipment Handled	Clearance Diagram	Current and Voltage	Contact Device	Special Const at Crossings Other Roads	Remarks
Pacific Elect. Ry., Los Angeles, Cal.	3|0 D-G	Max. 22'0" Steam Crs'gs' Std. 20'0" Min. 15'0"	953.93	1.84	Diagram Submitted	D-C 550	Trolley	Insulated crossings	
Portland Railway Light & Power Co., Oregon	4|0 Fig. 8	22'0" 18'0" 14'6"	216	None	A.R.E.A. Stand.	D-C 650	"	Patented O. H. Frogs	
Quebec Railway Light & Power Co.	2|0 Round	21'0"	39	39	None Submitted	D-C 550	"	Built according Specs. of Can. Ry. Comm.	
The Ohio Elect. Ry.	2|0-3|0 Grooved	22'0" 21'0" 21'0"	620	40	See Note	D-C 600 to 650	"	A.E.R.E. Assn.	Pole Line 8'0" from c.l. of track: buildings - 10 ft.
The Rhode Island Co.	2|0-4|0	22' at R.R. Cr'ings 19' to 20' 13' under Bridge	400m	5	None Submitted	D-C 600	"		
Toledo & Western Ry.	4|0 Fig. 8	21'0" 18'0" 18'0"	81	81	None Furnished	D-C 600	"	Basket the line over foreign lines	
Twin City Lines, Minneapolis, Minn.	2|0 Fig. 8	22'6" 18'0" 12'4"	400	1½	Have none	D-C 600	"	21'6" trolley above steam railroad tracks	
Union Traction Co., Indiana	2|0 & 3|0 Fig. 8 and Groove	22'0" 18' to 22' Std. 15±at Bridge	52 City 315 Interurban	2	Standard Line Const'n	D-C 600 to 650	"		Pole lines clear 7½' from c. l. of track.
United Rys. Co., Portland, Oregon	4|0 Grooved	23'0" 22'0" 17'8"	27.8	Note	None Furnished	D-C 600	"	Standard insulated crossings	During periods of extension, steam equip. used over all lines except 3 miles in city
Waterloo, Cedar Falls & Northern	4|0 Grooved	City—Interurban 22'0" 22'0" 18'6" 20'0" 15'0" 18'6"	50.86	37	None Furnished	D-C 650	"	A. T. & T. standard	Not including second track or sidings.

RECOMMENDATIONS.

(1) Your Committee recommends the adoption by the Association of Diagram "B," showing typical overhead clearance diagrams for permanent way structures and working conductors.

(2) Your Committee also recommends the continuation during the coming year of consideration of work now under way, particularly the consideration of the subjects of "Electrolysis," "Insulation," and "Location and Clearance of Automatic Safety Stops," and also the consideration of any new information that may develop in reference to "Maintenance Organization" and "Relation to Track Structures."

(3) Your Committee asks for such other directions or instructions as seem necessary or desirable.

Respectfully submitted for the Committee,

GEORGE W. KITTREDGE,

Chairman.

Diagram B.

RECOMMENDED OVERHEAD CLEARANCE LINES FOR PERMANENT WAY STRUCTURES ON ELECTRIFIED RAILROADS.

SUBMITTED BY COMMITTEE ON ELECTRICITY.

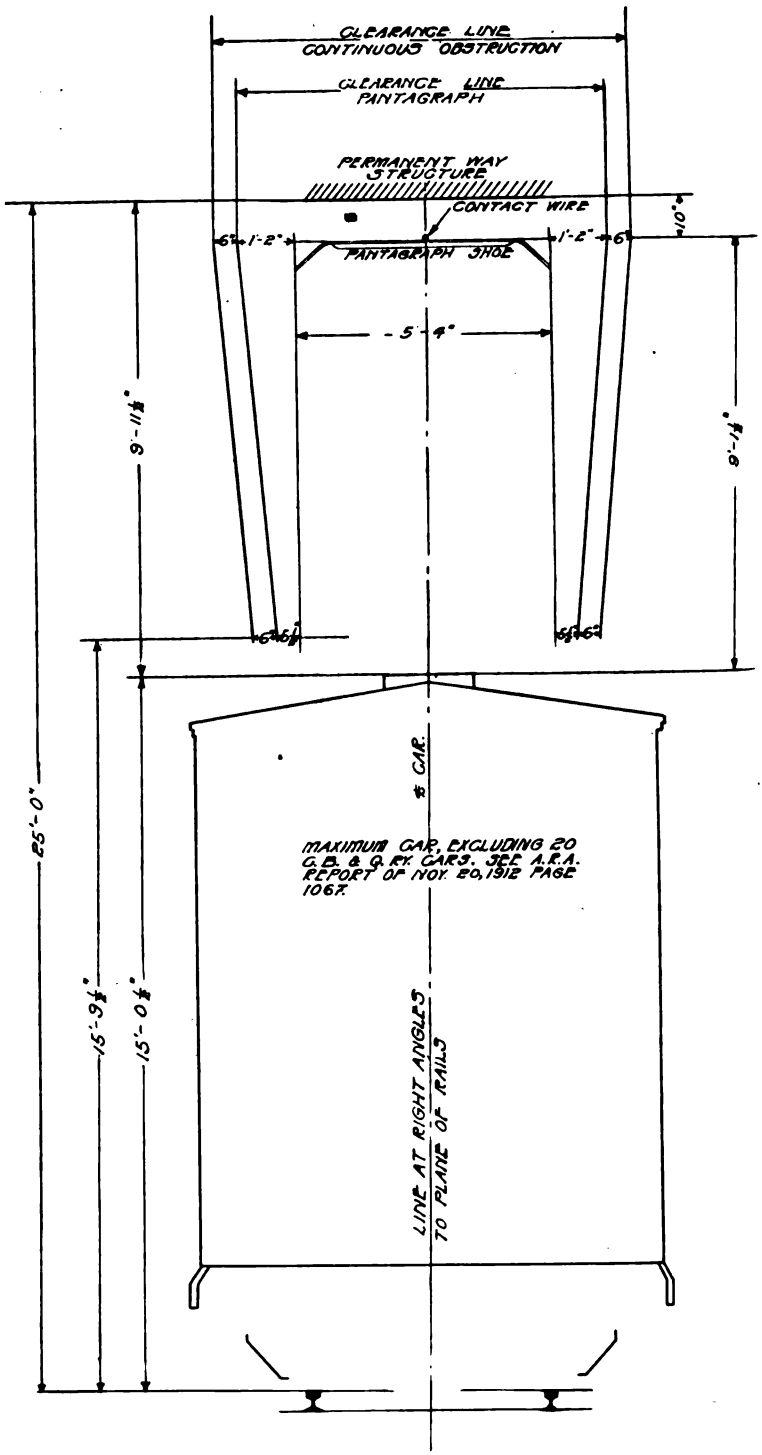
Notes.

Momentary obstructions, such as signal blades, may approach pantagraph clearance line.

Sway of pantagraph based on 1 in. difference in height of car springs; ½ in. difference in elevation of track rail, and sway of 6 in. either side at 22 ft. above top of rail for pantagraph itself.

These diagrams show minimum clearance; additional clearances will be required to provide for special features of design, sag between points of support as affected by length of span and temperature changes, and also for steady strains, pull-offs, etc., if any.

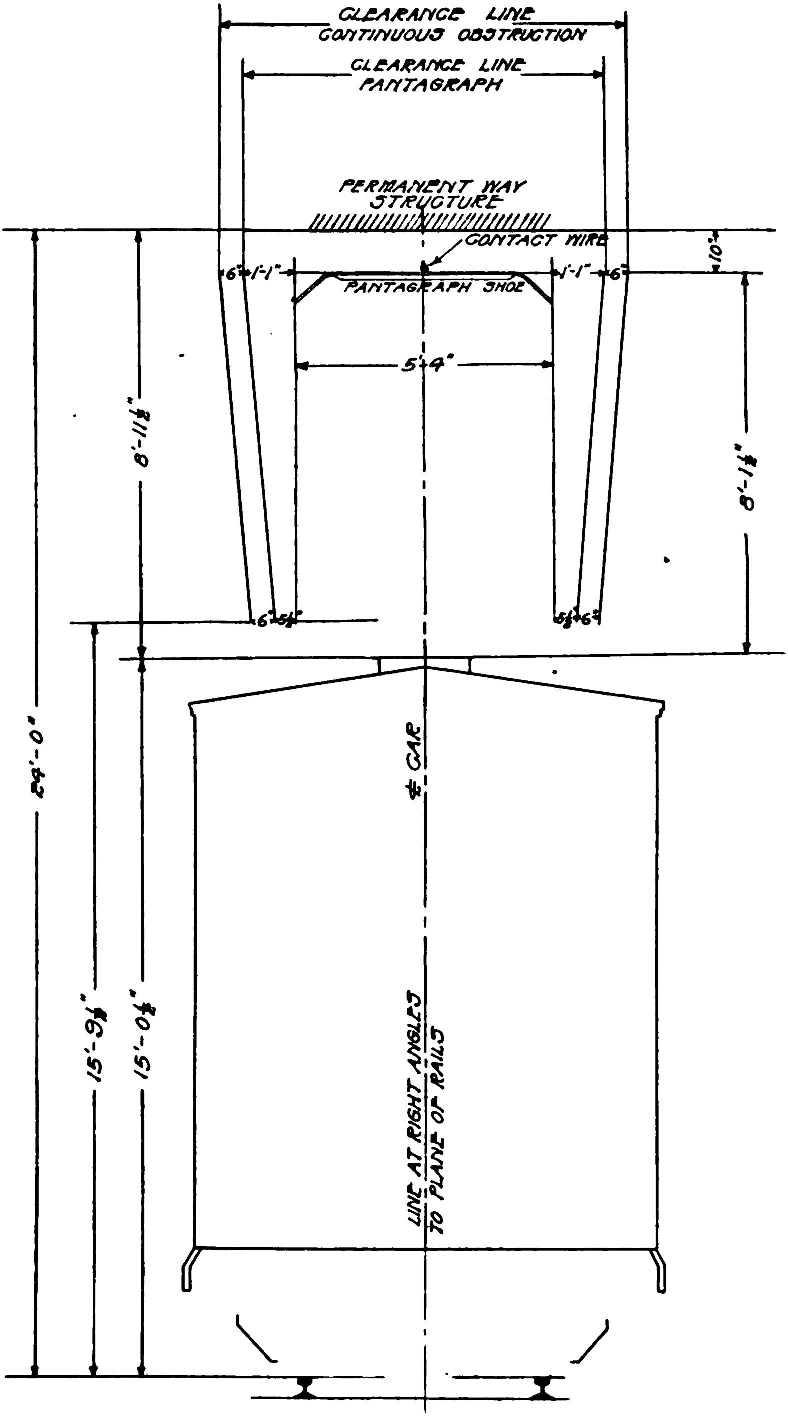
All heights to be measured at right angles to plane of rails at center line of track.



Case No. 1—Clearance for Trainman With Lantern.

ASSUMPTIONS.

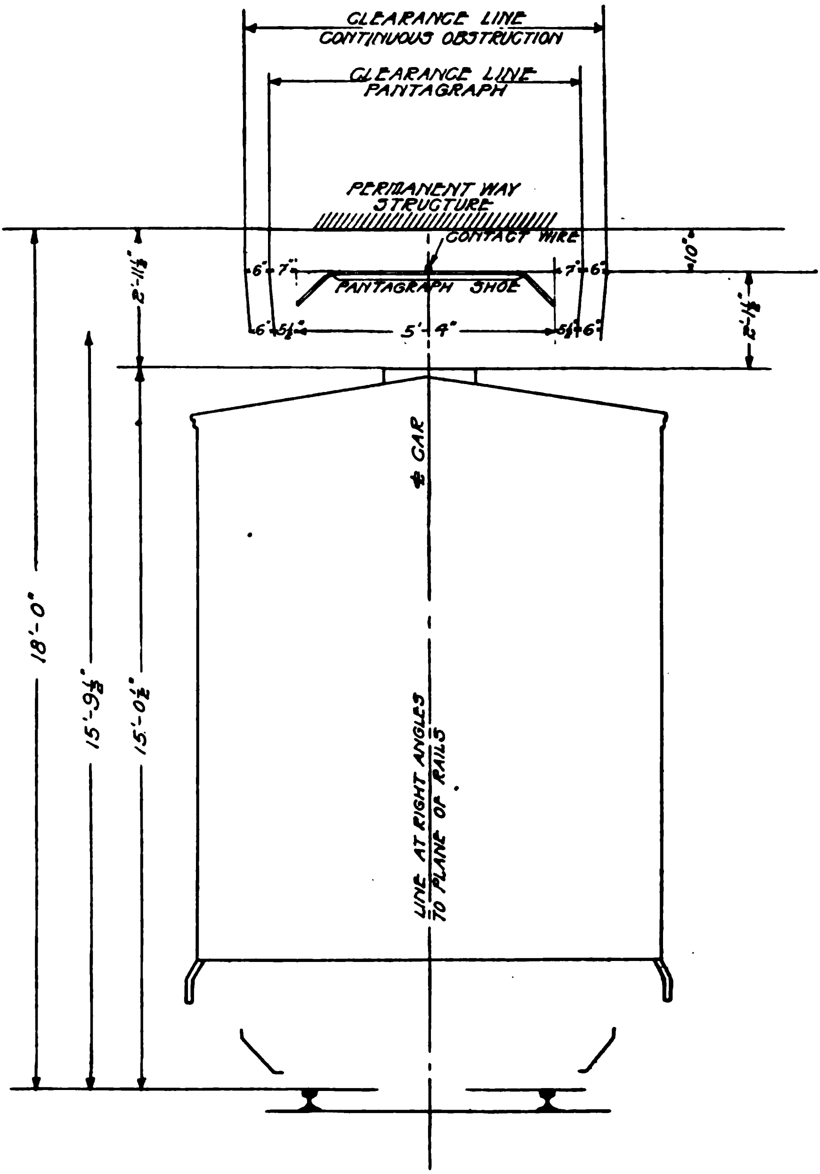
Reach of 6-ft. trainman	7 ft. 8 in.
Lantern Swing	1 ft. 0 in.
Clearance	0 ft. 5½ in.
Required distance car running board to wire	9 ft. 1½ in.



CASE NO. 2—CLEARANCE FOR TRAINMAN WITHOUT LANTERN.

ASSUMPTIONS.

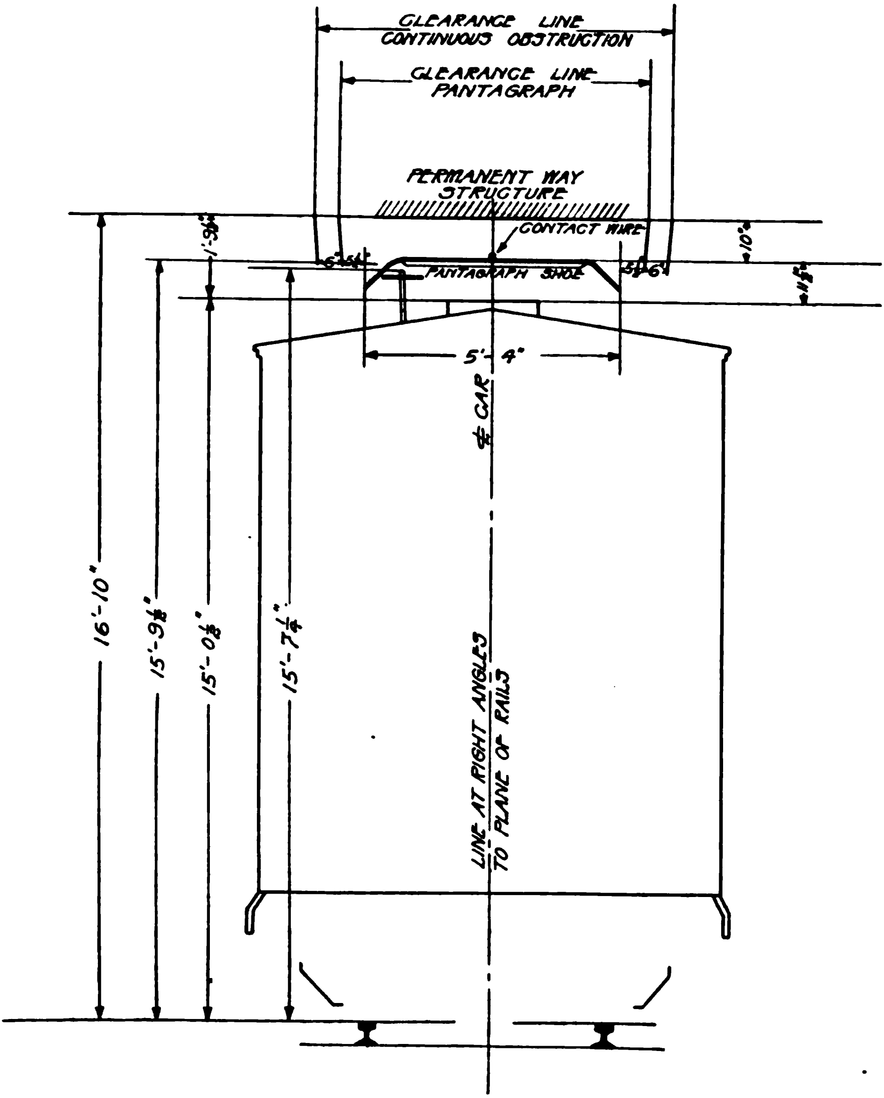
Reach of 6-ft. trainman	7 ft. 8 in.
Clearance	0 ft. 5½ in.
Total distance car running board to wire	8 ft. 1½ in.



Case No. 3—Normal Minimum Clearance Without Trainman on Cars.

ASSUMPTION.

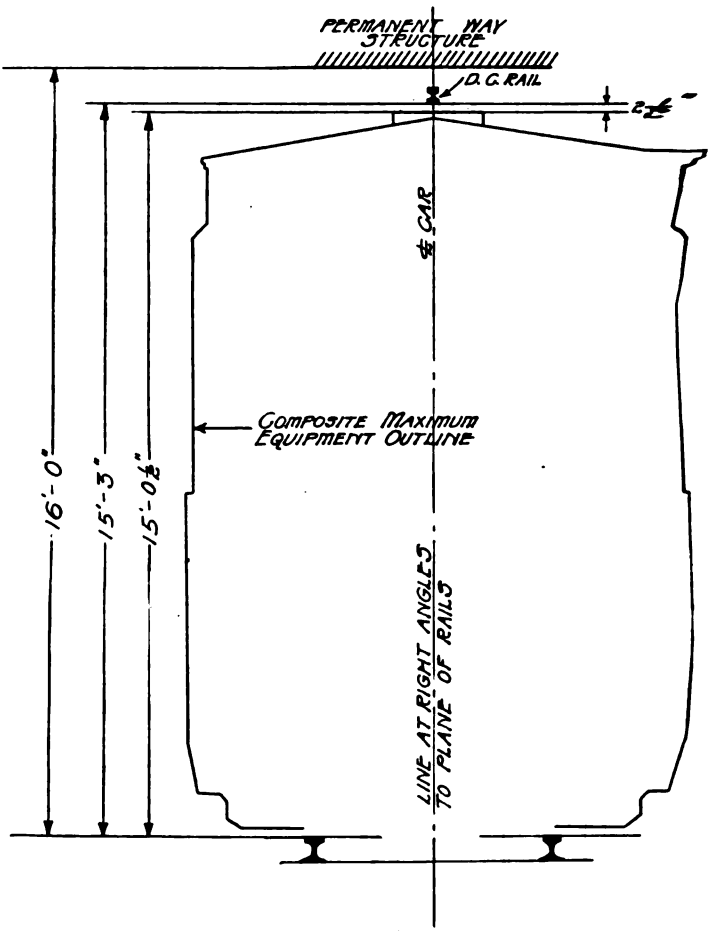
Normal distance car running board to wire..................2 ft. 1½ in.



Case No. 4—Special Minimum Clearance Without Trainman on Cars.

ASSUMPTION.

Minimum distance car running board to wire..............0 ft. 11½ in.



CASE NO. 5—MINIMUM CLEARANCE D. C. OVERHEAD.

ASSUMPTION.

Minimum distance car running board to rail.................o ft. 2½ in.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION.

EARL STIMSON, *Chairman;*
H. B. DICK,
C. F. FORD,
DR. W. K. HATT,
V. K. HENDRICKS,
JOS. O. OSGOOD,
E. H. BOWSER, *Vice-Chairman;*
GEORGE E. REX,
E. A. STERLING,
C. M. TAYLOR,
DR. H. VON SCHRENK,
T. G. TOWNSEND,

Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned to your Committee the following subjects:

(1) Continue investigations of the merits as a preservative of oil from water-gas and the use of refined coal tar in creasote oil.
(2) Continue the compilation of available information from Service Tests.
(3) Continue the investigation of the proper grouping of the different timbers for antiseptic treatment, conferring with Committee on Grading of Lumber.
(4) Report on methods of accurately determining the absorption of creosote oil.

The subjects were assigned each to a Sub-Committee for investigation.

Two meetings of your Committee were held in the Association rooms, Chicago, the first on September 25, 1913, those present being E. H. Bowser, C. F. Ford, C. M. Taylor and Earl Stimson, Chairman; the second, on December 10, 1913, those present being E. H. Bowser, C. F. Ford, Dr. W. K. Hatt, V. K. Hendricks, E. A. Sterling, T. G. Townsend, Dr. H. von Schrenk and Earl Stimson, Chairman.

(1) OIL FROM WATER-GAS AND COAL-TAR IN CREOSOTE OIL.

(a) MERITS AS A PRESERVATIVE OF OIL FROM WATER-GAS TAR.

The large railroad mentioned in last year's report as contemplating the use of a mixture of coal-tar creosote and oil from water-gas tar did not use this mixture, because the cost of the water-gas oil was too high. The Public Service Railroad Company has in use 25,000 ties treated in 1911, 75,000 treated in 1912 and 60,000 treated in 1913, with 10 lbs. per cu. ft. of oil from water gas. Arch Street, Philadelphia, has been paved with wood blocks treated with this oil, but too recently to get results. Some heavily-treated paving blocks at Baltimore have rotted after seven years' use, and the oil after extraction analyzed like oil from water-gas tar.

The Forest Service has compared a water-gas tar, specific gravity 1.058 at 60 Centigrade, and a coal-tar creosote, specific gravity 1.048 at 60 Centigrade, with the following results:

"The water-gas product seems to be absorbed as readily as the creosote, though its diffusion through the wood was very much poorer than creosote. In the volatility test the specimens were submitted to a constant temperature in dry air for 90 days. The specimens treated with water-gas tar lost 18 per cent., while the creosoted specimens lost 32 per cent. The inflammability of the wood treated with the water-gas tar product was about the same as creosoted specimens. In the toxicity tests, agar solutions of water-gas product up to three per cent. allowed a strong growth of fungus (*Fomes Annosus*), while 0.2 per cent. agar solutions of coal-tar creosote allowed a slight growth only, and 0.4 per cent. allowed no growth at all. Corrosive action of both substances on steel is negligible and neither can be used in wood whose surfaces are to be painted."

Partial tests of the Forest Service on mine timbers show that loblolly pine treated with 10 lbs. per cu. ft. of oil from water-gas tar, specific gravity 1.064 at 50 Centigrade, is economical. The life of these timbers necessary to be economical is 2¾ years, while the treated material has already lasted three years.

Preliminary tests in petri dishes of water-gas oil by the Forest Service show oil of gravity of 1.01 at 60 Centigrade to be about as strong antiseptically as ordinary creosote and oil of gravity of 1.06 at 60 Centigrade as having no antiseptic properties. Petri dish tests by A. L. Dean and C. R. Downs of the Sheffield Scientific School show that the water-gas tar creosote was almost identical in antiseptic power with the coal-tar oil with its tar acids removed. Petri dish tests by J. M. Weiss show that the water-gas tar distillate is one-sixth antiseptically as efficient as coal-tar creosote in preventing mould and that it has considerably lower antiseptic value than the coal-tar oils with acids, bases and solid hydrocarbons removed.

On account of the present lack of definite data as to its efficiency, its rising price and the uncertainty of its preservative value, it is thought not advisable at this time to recommend the use of oil from water-gas tar as a wood preservative.

(b) THE USE OF REFINED COAL TAR IN CREOSOTE OIL.

Your Committee has given careful consideration to the question of adding coal tar to creosote oil. The information collected clearly establishes the fact that a considerable amount of timber is being treated with a coal-tar creosote mixture; also, that present conditions governing the supply and cost of creosote oil indicate an increased use of the mixture.

Although the addition of coal tar to creosote is sufficiently extensive to require recognition, it is not a clearly defined practice as regards technical application. At the plants where the mixture is used, it is applied under conditions which vary from open specifications and a full understanding, to surreptitious use where not specified or allowed.

The Committee's investigations indicate that up to date the results obtained from the use of the coal-tar creosote mixture are not sufficiently definite, as to character of treatment and preservative qualities, to permit of specific recommendations as to its merits as a preservative. It is, however, the opinion of the Committee that coal tar should not be added to high-grade creosote, and it therefore submits the following recommendation for insertion in the Manual:

The Committee recommends that wherever possible only Grade 1 Coal Tar Creosote should be used, and that under no circumstances should coal tar be added to creosote of this grade.

While making only one definite recommendation, because of lack of information on which to base additional conclusions, the Committee realizes that on account of the inadequate supply of Grade 1 Creosote, and because of individual conditions or opinions, various roads may add coal tar to the creosote used. The Committee, therefore, advises that in such cases the following precautions be taken, it being clearly understood that these are appended without making any recommendations as to the advisability of the coal-tar addition to creosote:

Where it is thought advisable by any company to use coal tar, in mixture with the lower grades of creosote, i. e., Grades 2 and 3 of the American Railway Engineering Association, and poorer, the Committee recommends that the following precautions be followed, and they are submitted for adoption and insertion in the Manual:

(1) That there be a distinct understanding between all concerned that a mixture is specified and used.
(2) That the coal tar be added to the creosote only at the plant and under the direct supervision of the railway company.
(3) That under no circumstances should the coal tar added constitute more than 20 per cent. of the mixture.
(4) That the coal tar and creosote be thoroughly mixed at a temperature of approximately 180 degrees Fahrenheit before being applied to the timber, and that the mixing be done in tanks other than the regular working tanks, and that the tanks containing the mixture shall be heated and agitated thoroughly each time before any oil is transferred to the working tanks.
(5) That only low-carbon coal tar be used, the amount of free carbon not to exceed 5 per cent.
(6) That in treating with the mixture the temperature of the solution in the cylinder be not less than 180 degrees Fahrenheit.

There appears as Appendix A to this report a paper by Dr. Hermann von Schrenk, dealing with this subject in a comprehensive manner.

(2) RECORDS FROM SERVICE TESTS.

As Appendix B of this report will be found the record of service tests. This record is compiled from the reports of periodical inspection of the sections of test track on the various railroads conducting such tests.

Many of the tests have not been under way a sufficient length of time to show results. Attention is called to the following tests, which show some interesting results:

Chicago, Burlington & Quincy;
Galveston, Harrisburg & San Antonio;
New York, New Haven & Hartford;
Norfolk & Southern;
St. Louis & San Francisco.

(3) GROUPING OF TIMBERS FOR ANTISEPTIC TREATMENT.

Your Committee reports progress on this subject for this year. No new data was obtained on the subject of the proper grouping of timbers for treatment which would be of any material value.

There is so much variation in the absorptive powers of the different kinds of timber, the same kind of timber growing in different localities, and even timber from different parts of the same tree, that any definite and detailed rules for grouping so as to obtain exact results are impossible. Your Committee, however, has promises that some experiments will be made along this line during the coming year, from which it may be able to formulate a few general rules regarding the absorptive power of the different kinds of timber and also the absorptive power of the same kinds of timber with different percentages of sap and heartwood.

(4) METHODS OF ACCURATELY DETERMINING THE ABSORPTION OF CREOSOTE OIL.

A brief discussion of the present practice in determining the absorption of creosote oil in the treatment of timber is submitted as a basis for the consideration of new and improved methods. Three systems are in general use for determining the absorption of preservatives, as follows:

(1) By gage readings of tanks, with temperature corrections.
(2) By weighing the oil in the working tanks before and after treatment of charges in cylinder.
(3) By weighing the cylinder charges before and after treatment.

A description of these methods is given below:

(1) MEASUREMENTS BY GAGE READINGS OF TANKS, WITH TEMPERATURE CORRECTIONS.

This is the method in most general use at treating plants, and has two forms of application, as follows:

(a) The simplest form of gage reading is to measure the level of the oil from some fixed point on the top of the tank with a steel tape and plumb-bob. Common chalk rubbed on the plumb-bob indicates to what depth it has been lowered in the liquid.

of pulleys, to an indicator which moves up and down a graduated gage-board as the height of the oil in the tank varies, the gage-board being so placed as to be easily read by the operator.

Instead of this gage-board the wire from the float is sometimes connected with the drum of a recording gage. A system of properly designed gears, operated by this drum, causes a movement of the indicator hands over a dial graduated into feet and fractions thereof as the level of the oil in the tank changes. A counterweight is attached to the drum to offset the friction in the gears and pulleys.

Some of the causes of errors peculiar to float and gage readings are mentioned in Bulletin 126, Forest Products Laboratory Series, United States Department of Agriculture, as follows:

Change in position of float with change in its volume due to temperature.

Change in position of float with change in specific gravity of the oils.

Variation in length of gage wire or chain with change of temperature.

Change in volume of measuring tank with change in temperature.

Position of indicator as affected by resistance in the gage and difference in tension in the gage wire.

Inertia of the gage and friction of the pulleys.

The possible lack of uniformity in the temperature of the oil in the measuring tank at any given time.

The temperature of the oil must be taken and corrections of the volume made for temperature change. The temperature of the oil in the tank at time the gage readings are taken is determined either by:

(1) A long-stemmed thermometer, placed at the side of the tank a sufficient distance above the heating coils, so that its reading may not be affected; or

(2) Taking the temperature of a sample of oil representing an average of the entire contents of the tank, which may be obtained with an "oil thief," with an ordinary thermometer.

(2) MEASUREMENTS BY WEIGHING THE OIL IN THE WORKING TANKS BEFORE AND AFTER TREATMENT OF CHARGES IN CYLINDERS.

This heading may be divided into two classes:

(a) As determined by direct weighing.

(b) As determined indirectly by means of a mercury gage.

(a) In the first method the working tanks are mounted on scales with scale beam ordinarily graduated to 20 lbs. A type-registering attachment permits the recording of the weight.

Measurements of absorption, as determined by weight of oil taken from the working tank, makes it unnecessary to take temperature variation into consideration, thereby lessening the tendency for inaccuracy from that course. It requires frequent determination of the specific gravity of the oil in case the absorption of the treated material is desired in gallons, or by volume.

(b) Mercury gages have been installed in several creosoting plants. Their principle consists of counterbalancing a free column of oil in the working tank with a mercury column. In order to permit close reading of the mercury thread, the scale is usually set at an angle, to permit a larger scale and consequently closer reading.

The Shaw mercury tank indicator, as installed at the Atlantic Coast Line Railroad Company's treating plants, consists of a wide, hardwood base, reinforced longitudinally by two iron rods. Down the center runs a heavy glass tube, which holds the recording mercury and connects at the bottom with the mercury bath. The glass tube is flanked on both sides by graduated brass plates. On one side are scales in gallons for creosote oil for different gravities. On the other side the scale is graduated in pounds. The working tanks are connected by a ¼-in. pipe from a point near the bottom of the tank to the mercury bath.

(3) DETERMINATION OF ABSORPTION BY WEIGHING THE CYLINDER CHARGE BEFORE AND AFTER TREATMENT.

The use of track scales for the determination of the absorption of creosote oil in timber is very common. As a check of the oil as measured or weighed in the working tanks, it is very desirable and should be inaugurated as far as possible. It is only, however, where there is no appreciable loss of moisture and sap from timber during treatment that this method can be used with accuracy.

The volatility of creosote at the temperature at which treatment is ordinarily conducted is somewhat high, which necessitates the immediate weighing of the charge as soon as it is taken out of the cylinder in order to minimize the error in determining the absorption in this manner, because of the evaporation of the oil from the treated timber.

DISCUSSION AND CONCLUSIONS.

Absorption when determined either by gage readings or weights of the creosote in the working tank before and after treatment makes it necessary that either all oil in the pipe line and subsidiary tanks from working tanks to cylinder is returned to the working tank before readings are taken, or some method be devised for accurately determining such oil in pipe lines and subsidiary tanks and allowances made accordingly.

In case water is introduced in the creosote during the treating process, which is sometimes the case when timber is artificially seasoned in the cylinder, a determination of the water content of the oil in the working tanks before and after treatment must be made and the gage readings or weighings changed correspondingly.

Of the three systems practiced for determining creosote absorption, the weighing of the oil in the working tanks before and after treatment is considered best, although either of the other systems, when properly checked, is practicable.

Without attempting to make final recommendations at the present time, attention is called to the need of a more logical basis for absorption determination, and certain general modifications in practice are recommended. The term "accurate" under the present practice is only relative, since errors which make the determinations only approximate result from both the basic unit of absorption and from inaccuracies in readings and equipment.

The usual practice in treating specifications calls for a given number of pounds per cubic foot of timber, or a stated number of gallons per tie. In both cases the essential factor of penetration is ignored. What is wanted is maximum penetrations, which with most woods means complete penetration of the sapwood and of the heart to the extent possible with the kind and condition of the timber treated. The exceptions which occur—as in red oak, which gives heartwood absorption, and red fir, which resists even sap penetration—do not affect the general rule.

The fallacy of the present unit is evidenced by the fact that a specific absorption may be given in the outer inch of a two-inch ring of sapwood, which would not be good treatment. On the other hand, a 10-lb. treatment, for example, may be specified for a wood which is 60 per cent heart, resulting in a 25-lb. absorption in the treatable portion, with the consequent waste and expense. Moreover, oil is bought by the gallon at a specified temperature and injected into timber on a pounds-per-cubic-foot basis, thus complicating check of quantities and inventory.

While the difficulties of specifying the proper amount of oil for full penetration of the treatable portion of timber is realized, particularly at commercial plants, where costs must be definitely estimated in advance, it is believed that at railroad plants the best treatment for each particular class or kind of timber should be given and the costs based on the amount of oil used. If the various departments concerned feel it necessary, a maximum could be named, and if insufficient, it would simply result in lighter treatment in the treatable portions of the wood. In most cases it is believed this plan would effect a saving: Master carpenters, for example, are in the habit of specifying 12 lbs. for structural timber. When long-leaf pine dimension timbers are used, this often means 20 lbs. or more per cubic foot in the parts of the stick which absorb oil, which is more than is needed to prevent decay under normal conditions.

It is therefore recommended that at railroad plants the absorption be based on the treatment which will give the most complete penetration for each class or kind of timber, specifying complete penetration of the sapwood and as much of the heart as possible for the particular species or charge; payment to be based on the amount of oil used, plus operating and other charges.

Where railroads have their work done by contract, it is recommended that gallons be specified for ties, posts, cross-arms and other material of uniform size, and pounds per cubic foot for other material; the

same requirements as to sap and heart penetration to be applied as in the above.

It is also recommended that the Committee pursue investigations next year relative to a more definite and satisfactory basis for determining creosote absorption, and also of improved mechanical means of checking the absorption.

CONCLUSIONS.

It is recommended that the following be adopted by the Association and inserted in the Manual:

(1) (b) THE USE OF REFINED COAL TAR IN CREOSOTE OIL.

(1) Wherever possible only Grade 1 Coal Tar Creosote should be used, and under no circumstances should coal tar be added to creosote of this grade.

(2) Where it is thought advisable by any company to use coal tar in mixture with the lower grades of creosote, i. e., grades 2 and 3 of the American Railway Engineering Association, and poorer, the following precautions should be followed:

(a) That there be a distinct understanding between all concerned that a mixture is specified and used.

(b) That the coal tar be added to the creosote only at the plant and under the direct supervision of the railway company.

(c) That under no circumstances should the coal tar added constitute more than 20 per cent. of the mixture.

(d) That the coal tar and creosote be thoroughly mixed at a temperature of approximately 180 degrees Fahrenheit before being applied to the timber, and that the mixing be done in tanks other than the regular working tanks, and that the tanks containing the mixture shall be heated and agitated thoroughly each time before any oil is transferred to the working tanks.

(e) That only low-carbon coal tar be used, the amount of free carbon not to exceed 5 per cent.

(f) That in treating with the mixture, the temperature of the solution in the cylinder be not less than 180 degrees Fahrenheit.

(4) METHODS OF ACCURATELY DETERMINING THE ABSORPTION OF CREOSOTE OIL.

(1) At railroad plants the absorption should be based on the treatment which will give the most complete penetration for each class or kind of timber, specifying complete penetration of the sapwood and as much of the heart as possible for the particular species or charge; payment to be based on the amount of oil used, plus operating and other charges.

(2) Where railroads have their work done by contract, gallons should be specified for ties, posts, cross-arms and other material of uniform size, and pounds per cubic foot for other material; the same requirements as to sap and heart penetration to be applied as in the above.

OUTLINE OF WORK FOR 1914.

Your Committee recommends:

(1) Continue investigation of the use of coal tar in creosote oil.

(2) Continue the compilation of available information from service tests, supplementing this with reports of inspections to be made by members of the Committee, of those sections of test track that have been in service long enough to give results.

(3) Investigate the subject, "Water in Creosote."

(4) Prepare specifications for timber to be treated.

(5) Report on a more definite and satisfactory basis for determining creosote absorption and improved mechanical means of checking the absorption.

Respectfully submitted,

COMMITTEE ON WOOD PRESERVATION.

APPENDIX B.

RECORD OF TIE SERVICE TESTS.

Appendix A.

THE USE OF REFINED COAL-TAR IN THE CREOSOTING INDUSTRY.

BY HERMANN VON SCHRENK AND ALFRED L. KAMMERER.*

For some years it has been the practice in a number of plants to add a certain percentage of refined low-carbon coal-tar to creosote oil of a certain grade. By "certain grade" a creosote oil is meant which has a specific gravity of approximately 1.03, or less, at 100 degrees Fahrenheit. This addition was made because it was found that by adding a small percentage of coal-tar to creosote of this grade, it was possible to make a heavier grade oil. A good deal of discussion has been aroused during recent years as to the propriety of adding refined coal-tar to creosote oil. In view of the fact that this practice has now grown to considerable proportions, it was thought advisable to prepare a brief statement, outlining the best information available with respect to this subject at the present time.

So far as known to the writers, refined coal-tar was first added, in the United States, as a matter of standard practice, to creosote oil used in the treatment of cross-ties early in 1908. Since that time similar additions to creosote oil have been used at a number of large plants in various parts of the country. At about the same time that treatment was begun with the combination of refined coal-tar and creosote oil for the treatment of cross-ties, a similar practice started for the treatment of wooden paving blocks. The best information available indicates that this practice was inaugurated about 1907. Since that time, with few exceptions, the paving blocks treated in the United States have almost all been treated with a combination of coal-tar and creosote. The standard specifications of the Committee of Street Engineers, issued in 1910, specifically requires such a combination, and the use of the heavy oil thus produced is now standard for the treatment of paving blocks in the largest cities of this country.

THE AMOUNT OF CREOSOTE-TAR COMBINATION USED.

While it is not possible to give accurately the amounts of creosote and coal-tar used in combination, approximations can be made. From figures in possession of the writers, it has been found that since 1908, approximately 24,500,000 cross-ties have been treated and laid, treated with coal-tar-creosote mixture at plants where the mixture was specifically specified. In addition to this number, a number, which it is impossible to estimate, has been treated at other plants, and the total number would

*The writers wish to express their appreciation for co-operation and assistance given in this investigation by officials of the New York Central Lines. C. I. & L. and A. T. & S. F. Railroads, and the Federal Creosoting Company.

probably considerably increase the number first given. The reason it is impossible to give any accurate figures is because at many creosoting plants a mixture of coal-tar and creosote has been used for the treatment of ties and other materials on a straight creosote specification, without any mention of the fact that it is actually a mixture. The figures given by the writers are taken from the output of plants in which the coal-tar and creosote are mixed *at the plants* as a matter of standard practice. The twenty-four and a half million ties referred to have now been in the track anywhere from one to five years; that is, approximately five million ties have been laid annually since 1910. Assuming that each tie was treated with approximately two and one-half gallons of oil, and using the year 1912 as a basis of comparison, that means that there were used in 1912 approximately 12,500,000 gallons of the coal-tar-creosote combination at plants where this combination is required as standard practice. The total creosote oil used for all purposes in 1912 (see Proceedings of the American Wood Preservers' Association, 1913) was 83,666,490 gallons. In other words, for the plants referred to, the amount of oil used equalled about 14 per cent. of the total oil used.

Taking the paving blocks, according to the United States Forest Service, there were used, in 1912, 7,091,058 cu. ft. of paving blocks, and estimating that approximately two gallons of oil were used per cu. ft., this would make 14,182,116 gallons, or approximately 17 per cent. of the total oil used. Taking the oil used for the treatment of ties and paving blocks together, brings the quantity of coal-tar-creosote combination used to about 31 per cent. No deduction has been made in this connection for paving blocks treated with straight creosote oil, but it is believed that any error in this connection will be largely offset by adding to this amount the amounts of creosote and coal-tar used at plants where no specific mention is made that such a combination is being used, and from which plants no statistics are on that account available. The writers believe that a very conservative estimate would show at least 40 per cent. of all the oil used at the present time in the United States to be a coal-tar-creosote combination.

WHAT COAL TAR IS.

There seems to be considerable misunderstanding as to exactly what the compound is which is being added to creosote. Numerous references have been made from time to time referring to coal-tar additions in the sense of an "adulteration." Briefly stated, coal-tar is produced as a by-product in the destructive distillation of coal. Two distinct sources of this material should be recognized, one the product obtained in the destructive distillation of coal in by-product coke-ovens; the other, the product resulting from the destructive distillation of coal at retort gas works. These products are usually referred to as "coke-oven tar" and "gas-house tar."

A very instructive summary of the practice of coal-tar distillation and refining was presented in a paper by R. P. Perry, before the Eighth International Congress of Applied Chemistry, New York, 1912 (reprinted in the Journal of Industrial and Engineering Chemistry, Vol. 5, page 151, 1913).

The crude coal-tar, that is, the tar as it is first collected, is usually subjected to various processes of refinement, meaning by this the removal of water and the subsequent breaking-up of the coal-tar into various fractions. The substance usually referred to as refined tár (pertaining to the additions of coal-tar to creosote) is the crude tar from which the water and low-boiling oils have been removed. In other words, the refined tar is the crude coal-tar from which the lightest boiling oils and water have been taken. Creosote oil is one of the fractions of crude coal-tar obtained by the distillation of the coal-tar. It is a fraction coming off between the benzol and carbolic-acid compounds, which come off at low temperatures, and the pitch, which remains in the still at the highest temperatures. Creosote is therefore a part of coal-tar. Creosote has usually been made from gas-house tar, although large quantities are now being made from coke-oven tar. The principal point pertinent to this discussion is that creosote, as it is usually known, is simply a fraction of crude coal-tar.

Reference has been made to the fact that there are two types of coal-tar: gas-house tar and coke-oven tar. These two are practically identical so far as their chemical composition is concerned, but they differ very radically in one respect, namely, the percentage of free carbon found in the tar. Without going into details as to reasons (see Mr. Perry's article), it may be stated that the coke-oven tar usually has a low percentage of free carbon, the retort coal-gas tar a comparatively high percentage of free carbon.

In the following table five analyses of by-product coke-oven tars are given and five analyses of retort coal gas tars made in our laboratories: (See Note).

NOTE.—The analyses of coke-oven tars here given represent samples taken from tars which have actually been used for the treatment of ties. These tars are examples of low-carbon coke-oven tars. Tars produced from coke-ovens are not necessarily low-carbon tars. The amount of free carbon in tars will depend on the type of ovens in which the coke is made. In general, the Otto Hoffman ovens will yield tars with high percentages of free carbon, the Semet-Solvay ovens a low percentage, and the Koppers ovens the lowest percentage. The following table is quoted from Public Roads Circular 97, and shows the possible range of free carbon found in tars from various types of coke ovens:

Type of Oven.	Percentage of Free Carbon. Minimum.	Maximum.	Average.
Koppers	2.81	3.95	3.38
Semet-Solvay	4.04	9.00	6.74
United Otto	5.26	12.55	9.00
Otto Hoffman	8.62	14.69	12.16
Otto Hoffman and United Otto (mixed)	11.51	13.52	12.51
United Otto and Rothberg (mixed)	17.17	17.17	17.17

For more detailed information see papers by S. R. Church, "Tar and Its By-Products" (Gas Age, May 15, 1913), and "Coke-Oven Tars of the U. S.," Office of Public Roads Circular 97.

By-Product Coke Oven Tars.

Source.	Semet-Solvay, Ensley, Ala.	Semet-Solvay, Ensley, Ala.	Barrett Mfg. Co. Chicago, Ill.	Indiana Steel Co. Gary, Ind.	Illinois Steel Co. Joliet, Ill.
Sample Number	835	1212	983	1750	1752
Sp. Gr. at 38° C.	1.150	1.183	1.170	1.156	1.160
Free Carbon	4.5%	6.2%	4.3%	2.7%	2.7%
Distillation:					
210° C.	2.7%	1.5%	0.8%	0.6%	1.8%
235° C.	3.8	3.6	3.2	5.6	7.4
270° C.	9.5	8.7	8.8	8.0	9.4
315° C.	6.6	7.0	8.9	8.0	6.0
355° C.	7.5	12.2	11.5	14.5	15.8
Residue	69.9	66.7	66.8	63.3	60.2

Retort Coal Gas Tars.

Source.	Barrett Mfg. Co. Phila., Pa. (a)	Burt, Boulton & Haywood. County Tar. London, Eng.	Laclede Gas L. Co. St. Louis, Mo.	West United Gas & Elec. Co. Aurora Ill.	Gas Co. Indpls., Ind.
Sample Number	286	611	690	860	1170
Sp. Gr. at 38° C.	1.157	1.175	1.163	1.218	1.221
Free Carbon	14.6%	(b)	24.5%	23.8%	27.9%
	(a) Mixed Tar.	(b) Not determined.			
Distillation:					
210° C.	3.6%	4.7%	2.9%	9.6%	1.8%
235° C.	5.5	12.2	4.1	1.2	1.8
270° C.	} 15.7	6.8	7.0	3.5	3.1
315° C.		4.5	6.3	5.2	8.9
355° C.	11.2	6.9	8.3	} 80.5	6.8
Residue	63.0	64.6	70.0		76.3

A comparison of the figures given in this table will show that there is a great similarity in the fractions of the two types of tar. Also, that while there is a difference in their specific gravity, the difference is not very marked.

Where refined tar has been added as a matter of standard practice, only low-carbon by-product coke-oven tar has been used. Retort coal-gas tar and certain grades of coke-oven tars are absolutely unfitted for the addition to creosote oil because of their high free-carbon content, unless this is removed either by mechanical methods or by filtration. It is possibly true that at many of the plants where coal-tar has been added to creosote oil, sufficient care has not always been used to see to it that only a low-carbon tar has been used. In other words, the writers are of the opinion that in many cases improper tars have been used.

The principal points summarized in this chapter are:

1. Crude coal-tar is produced from by-product coke-ovens and retort gas plants.
2. The coke-oven tar has a comparatively low percentage of free carbon; the retort coal-gas tar has a comparatively high percentage of free carbon.
3. Creosote oil is made from coal-tar, obtained both from gas-house tar and coke-oven tar.

4. Refined tar, as used in the discussion pertaining to the addition of refined tar to creosote oil, is, or should be, a low-carbon coke-oven tar; or coke-oven tar or gas-house tar from which the carbon has been removed by filtration or otherwise.

Reference has been made to the fact that most of the creosote oil was formerly produced from gas-house tar. The question was frequently asked why the manufacturers of by-product coke-oven tar did not refine the same and produce the creosote oil just as was done from the gas-house tar. Referring to this point, Mr. Perry says: "For many years there was very little coal-tar produced in this country, except from gas works operated at very high heats, and the tar was extremely viscous, of high specific gravity, and often containing from 30 to 40 per cent. free carbon. It was very difficult and expensive to distill such tar because of the percentage of water which it always contained, and the tendency for the excessive carbon to coke on the still bottoms and cause them to burn out. Because of this extreme, the lower carbon coke-oven tars were welcomed as of relatively better quality, but to-day they are not necessarily more valuable, as they yield pitches which are extremely subject to temperature influence—being very brittle when cold and easily flowing when heated—and therefore unsuited for many pitch uses in the United States." The writer's impression, however, is that the manufacture of creosote oil from coke-oven tar is largely increasing.

PREVIOUS USES OF COAL-TAR.

The impression has prevailed in many places that the use of the coal-tar addition to creosote oil, is a new proceeding. It may be of interest to note, therefore, that this is by no means the case. John Bethel, frequently called the "father of the creosoting industry," took out his patent, which may be regarded, as stated by Mr. Boulton, as the origin of the so-called creosoting process, in July, 1838. In this patent he specifies a mixture consisting of coal-tar thinned from one-third to one-half of its quantity with dead oil distilled from coal-tar. Quoting from Mr. Boulton's classic paper on the "Antiseptic Treatment of Timber": "It has been seen that Mr. Bethel's original patent recommended the use of the mother liquor, or coal-tar thinned with a portion of heavy coal-tar oil, so late as 1849. Bethel's license for the use of his patent described the patent as 'saturating timber with the oils obtained by a distillation of gas tar, either alone or mixed with gas tar.' The author remembers how, in the early days of creosoting, inspectors frequently refused to allow the thinner and lighter dead oils to be used without being thickened with tar. Tar, the mother liquor, necessarily included all the substances contained in the dead oils, plus the naphthas and pitch."

The use of the crude tars added to the coal-tar or dead oil was gradually abandoned, due to the fact that it was recognized that the crude naphthas evaporated from the wood, owing to their low-boiling points and because it was believed that the pitch contained in the tar,

when added in such large quantities as was then the practice, interfered with the proper injection of the oil. The use of a slight addition of tar has, however, not been abandoned in England.

The writers have repeatedly observed that at most of the creosoting plants in England, particularly the commercial plants, coal-tar is being added to creosote oil to-day largely for the curious reason that it is impossible to make prospective purchasers regard timber as properly creosoted if creosote oil alone is used, because it has a very light brown color. The average consumer demands that creosoted timber looks black, hence a slight addition of coal-tar is made even at the present day. A noteworthy point brought out by Mr. Boulton is the statement that as the coal-tar is the mother liquor of creosote oil, it practically must contain all the compounds which creosote itself does.

WHAT HAPPENS WHEN COAL-TAR IS ADDED TO CREOSOTE OIL.

The relation between coal-tar and creosote oil, when the same are mixed, is of prime importance. The combination of the two has, unfortunately, been termed "a mixture." It would be much better to state that the relation of the two is in the nature of a solution. The term "mixture" implies that the relation of the two substances is really one such as is found when two unlike substances are mixed. As an actual matter of fact, the two materials have approximately the same chemical constituents, and when coal-tar is added to creosote oil, the two substances combine so thoroughly that it is impossible to separate them by any physical process and, likewise, by any chemical process. That this is actually so can be clearly demonstrated by adding coal-tar to creosote oil and examining the resulting combination. An experiment was made to demonstrate this more clearly.

Fifty per cent. by weight of coal-tar (sample No. 1947) was added to 50 per cent. creosote oil (sample No. 1946). After the addition, the mixture was thoroughly heated and stirred for an hour or more. The resulting solution was then poured into a long glass tube and the tube was tightly stoppered. The following determinations were made:

Specific gravity of mixture at 100 degrees F. = 1.099
Specific gravity of creosote used at 100 degrees F. = 1.042
Specific gravity of coal-tar used at 100 degrees F. = 1.163

The tube was allowed to stand undisturbed for 13 months. The cork was then removed, and by means of a pipette successive layers or sections of the oil were carefully withdrawn, starting at the top. Approximately five equal sections were withdrawn and these were put into separate cylinders. The specific gravity of each section was determined separately. In the following table the successive sections are numbered, starting from the top, i. e., the top is section No. 1, the next is section No. 2, etc., and the bottom portion being section No. 5. The gravities found were as follows:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Sp. Gr. at 100 degrees Fahrenheit..	1.0970	1.0970	1.0971	1.0980	1.1006

The bottom of the tube contained a slight sediment of free carbon.

The conclusion drawn from this test, extending over a year, is that where a proper mixture of coal-tar and creosote oil is made and allowed to stand, no physical separation of the two substances takes place. The slightly lower specific gravity of the upper portions of the column are no doubt due to the settling out of the free carbon. To this is also due the slightly higher specific gravity of section 5, that is, the one nearest the bottom of the tube. Even if the slightest physical separation had taken place, the portions near the top of the tube would certainly have been very much lighter than was actually the case. The difference in the specific gravity of the upper layers, as found after a year, as compared with the specific gravity at the beginning of the test, is practically insignificant. When one remembers that this mixture was composed of one-half coal-tar and one-half creosote oil, it appears reasonable to conclude that when the proportions are on a basis of four parts of creosote oil and one part of coal-tar, the tendency for any separation would be still less than with the higher proportion.

The combination of coal-tar and creosote oil acts in every way like a heavier creosote. In fact, it requires a chemical determination of a somewhat refined character to be perfectly sure that any particular sample of creosote oil has had coal-tar added to it. There is nothing at all extraordinary about the fact that the two substances practically become one when it is remembered that coal-tar is the mother liquor from which creosote oil is distilled.

The statement has frequently been made that the coal-tar addition to creosote oil is in the nature of an adulteration. The Century dictionary defines the word "adulteration" as follows: "To debase or deteriorate by an admixture of foreign or baser materials or elements." It would appear perfectly obvious from the discussion just presented that coal-tar can in no sense be considered a baser or foreign material to creosote, especially in view of the fact that creosote is obtained from coal-tar. The word "adulteration" used in the ordinary accepted sense cannot be applied to the addition of coal-tar to creosote oil.

RELATION OF EVAPORATION.

One of the principal reasons why coal-tar has been added to low-gravity creosote oils was to obtain an increased permanence for the resulting combination after it has once been injected into wood. The results of a good many years' experience in the use of creosote oil has shown that after creosote is injected into timber, a certain percentage evaporates from the wood. These percentages will be highest where creosote oils of low specific gravity are used. In other words, where creosote oils are used having comparatively high percentages of low-boiling compounds, a higher percentage of evaporation takes place. The most recent recommendations of all those who have made a study of the proper grade of creosote oil to be used in the treatment of timber are to the effect that the best results will be obtained by the use of the heaviest coal-tar creosotes. In Bulletin No. 93 of this Association, the

results of an extensive investigation on the lasting power of timber were presented. The principal result of the investigation showed "a very marked evaporation of the low-boiling fractions of the creosote oil." As a result of this investigation, the writers urged as a standard specification for creosote an oil having a comparatively small amount of low-boiling compounds. The specification then recommended was subsequently adopted by the American Railway Engineering Association, and is now the standard creosote oil No. 1 of the Association. In 1911, one of the writers presented a discussion before the National Electric Light Association, giving the results of further European studies in connection with the use of creosote oil. Quoting from a report of the British Postoffice Department, made after an investigation of a large number of telephone poles, Mr. Henley, of the British Postoffice Department, concluded: "It would seem, therefore, that the opinion put forward by Mr. Boulton is justified (Mr. Boulton urged the constituents of heavy creosote oil), and that the heavier portions are the most durable and effective." In view of the practical agreement of all recent investigations, it can hardly be doubted that the heavy constituents of the creosote oil are the more stable and permanent ones.

With the large amount of creosote oil being used in the United States at the present time, a great deal of oil is offered for the creosoting of wood which does not fulfill the American Railway Engineering Association specification No. 1, that is, these oils have comparatively high percentages of low-boiling compounds. The writers have contended for many years that the use of such oils, except when they are used in larger quantities, will not give as good results as the use of the American Railway Engineering Association specification No. 1, particularly where such oils are used with one or the other of the so-called economical creosoting processes.

In order to determine what rate of evaporation occurs in creosote oils of various types, a large number of tests have been conducted during the last three or four years, the results of which are of particular interest at this time. Attention is here called to three series of these tests. In the first test (see chart No. 1) three creosote oils were taken, one a very light oil, the second a medium oil, and the third a heavy oil. Great care was exercised in the selection of the samples. Each of these oils is a pure creosote as distinguished from a made-up creosote; that is, they come from different sources and are the product of direct distillation of one tar. A weighed quantity of each oil was put into an open pan, and these pans were set out in the laboratory. They were weighed from time to time, and the percentage loss was determined. On chart No. 1 the percentage loss is shown graphically for a period of 955 days, that is, covering a period of almost three years. The analyses given on the chart show that these oils differ very materially in their specific gravities, and also that they differ considerably in their relative constituents. A marked difference will be noted between the percentage of low boiling compounds in oils contained in pans Nos. 29 and 36 compared

with the oil contained in pan No. 28. After almost three years, the lightest oil lost 50.1 per cent., the medium oil lost 48.5 per cent., and the heavy oil 32.6 per cent.

In view of the fact that the results obtained with the evaporation from pans are not exactly comparable to the condition of the oil when injected into timber, a second series of experiments was undertaken. Six different oils were chosen. Samples of these oils were placed in open pans, as in the first series, and in addition, a number of maple and pine blocks were treated with the different oils. The blocks of wood were carefully kiln dried for a considerable period, so as to be perfectly sure that they contained no water. The blocks of wood were kept in the laboratory in close proximity to the oil samples in the pans. They were weighed from time to time for a period of 376 days. Chart No. 2 shows the character of the oils used; chart No. 3 shows the results obtained from the evaporation series in open pans; chart No. 4 shows the same from maple blocks, and chart No. 5 shows the same from the pine blocks. In the case of the maple and pine blocks, the percentage loss is figured on the basis of the actual amount of oil injected. Referring to chart No. 2, oil No. 1 is a light American creosote; oil No. 6 is a heavy German creosote; oils Nos. 2, 3 and 4 were made up by redistilling oil No. 1 and omitting certain of the fractions. Oils Nos. 2 and 3 were so prepared as to have approximately the same fractions from 210 to 235 degrees, oil No. 2 having a higher fraction up to 210 degrees than oil No. 3. Oils Nos. 3 and 4 were so prepared as to have approximately the same percentage distilling up to 210, and with a larger fraction up to 235 in oil No. 3 than in oil No. 4. Oil No. 5 is a mixture of 80 per cent. oil No. 1 and 20 per cent. of coal-tar. The per cent. of fractions is shown on chart No. 2 on a cumulative basis. A glance at this chart shows that there was a wide variation between Nos. 1 and 6. Referring to chart No. 3, showing the percentage of loss from open pans, it will be noted that the rate of evaporation was in the order 1, 5, 2, 3, 4 and 6. By consulting chart No. 1, it will be noted that by adding fractions up to 235, and arranging the oils in the order of the highest quantities distilling up to 235, one obtains the series 1, 5, 2, 3, 4 and 6. This, it will be noted, is exactly the order in the evaporation series from open pans, beginning with the oil which lost the highest amount. Turning to chart No. 4, showing the percentage of evaporation from maple blocks, it will be noted that, starting with the oil which lost the highest amount, the order is again 1, 5, 2, 3, 4 and 6. Turning to chart No. 5, showing the evaporation of various creosote oils from pine blocks, it will be noted that the order is again 1, 5, 2, 3, 4 and 6. The percentage evaporating from the pine and maple blocks shows in an even more striking manner than in the open pan series that the oils having the highest percentage of low-boiling compounds disappear from the woods with relatively greater rapidity than do the oils having a low percentage of low-boiling compounds. Referring specifically to oil No. 5, this being the mixture of 80 per cent. oil No. 1 and 20 per cent. coal-tar, it was

found in the open pan series that whereas oil No. 1 lost 67.8 per cent., oil No. 5 lost only 57.2 per cent. In the maple block series, the maximum loss for oil No. 1 was 69.7 per cent., while oil No. 5 lost only 53.4 per cent. (The lower percentage loss according to the last weighings on charts Nos. 4 and 5 are without doubt due to moisture absorption. The period immediately preceding the last weighing on April 24 was a very wet and rainy week). In the case of the pine blocks, the highest loss for oil No. 1 was 71.6 per cent., while for oil No. 5 the highest loss was 54 per cent. These results show in a most striking manner that, so far as the percentage loss by evaporation is concerned, the coal-tar addition certainly reduces the percentage loss. A comparison is invited between the rate of evaporation of oils 1 and 5, that is, the light creosote oil and the same creosote oil with 20 per cent. coal-tar addition, as shown on charts Nos. 3, 4 and 5. It will be noted that the difference in the actual rate of evaporation is very much higher in charts Nos. 4 and 5, representing the evaporation from actual wood, than it is in chart No. 3, representing the evaporation from open pans. It would therefore appear that there is something in the creosote-coal-tar mixture which very materially reduces the loss of the lighter boiling fractions. A possible explanation may be that the heavier and more solid constituents of the oil block up the outer cells of the wood. United States Forest Service Circular No. 188 says: "It may be inferred that the creosote, to be of the most value at least for treating loblolly pine, should contain considerable quantities of high-boiling fractions, which appear to block up the outer cells and so insure the retention of the lighter oils in the interior of the wood."

There are certain other interesting points in connection with this test, but as they are of less interest at this point, they will be discussed elsewhere. An important feature of the experiment is that it indicates that the evaporation from pans may be taken as a fair index of the rate of evaporation of the same oils when contained in wood.

A third series of experiments was conducted to determine the influence of the coal-tar addition on creosote oil. In this series of tests a heavier creosote oil than in the second series of tests was used. Two sets of oils were placed in open pans. In one case an English creosote oil was used (pan No. 36), a coal tar (pan No. 38) and a mixture of the two composed of 70 per cent. creosote and 30 per cent. coal-tar. The per cent. loss, due to evaporation, in this series is diagramatically illustrated on chart No. 6. Chart No. 7 shows a similar series, in which in addition to the mixture of 70 per cent. creosote and 30 per cent. coal-tar, a pan with 80 per cent. creosote and 20 per cent. coal-tar was set out. Both series cover a period of a little over two years. In both cases it will be noted that the per cent. evaporating was materially reduced as a result of the addition of the coal-tar.

A fourth series of evaporation tests was conducted at two creosoting plants, one at Toledo, Ohio, and the other at Shirley, Ind. The creosote oil actually used at the plants was chosen for one set of pans, the tar

actually used for another, and a mixture of 20 per cent. coal-tar and 80 per cent. creosote oil, as actually used in the daily treating operations, formed a third set of pans. Two sets were set out at Toledo, one started in September, 1911, the other in November, 1911. These two sets of pans have therefore been exposed a little over two years. In the same way a set of pans was exposed at Shirley, Ind. The results of these tests to date are shown on charts Nos. 8, 9 and 10. In all three cases the mixture of creosote oil and coal-tar shows a decidedly smaller loss than the creosote oil itself.

In all of these evaporation tests, the reduced rate of evaporation is doubtless due to the smaller percentage of low-boiling oils. It is too soon as yet to determine what the ultimate difference will be of the creosote oils, such as were used in the experiments, and the same creosote oils mixed with a small percentage of coal-tar. The present plan is to leave these pans until the evaporation curve reaches a fairly straight line. It is then proposed to determine the composition of the residue in each case. Sufficient information, however, is at hand to indicate that the addition of coal-tar to creosote oil gives assurance that a larger quantity of the original oil injected will remain in the wood than would have been the case if the creosote oil had been used by itself.

RELATION OF ANTISEPTIC PROPERTIES.

For the last 50 years there has been a continued discussion as to which of the component parts of creosote oil should be regarded as the most valuable from an antiseptic standpoint. In spite of very considerable investigation, there is as yet no conclusive evidence as to which of the constituents of creosote oil are the most valuable from an antiseptic standpoint. J. M. Weiss (Journal of Chemical Industry) reports the results of a series of culture tests with various portions of creosote oil. Without going into a detailed discussion of these tests, the criticism may be presented that the results can hardly be regarded as conclusive from the standpoint of wood preservation, in view of the fact that the fungi tested were chiefly molds and had no relation whatever to the decay-producing forms. It is a well-known fact that different species of fungi act very differently towards antiseptics, and in so important a discussion as this the results of culture tests made with mold fungi are at least open to serious doubt.

H. F. Weiss, in a paper presented before the Eighth International Congress of Applied Chemistry (see Journal of Industrial and Engineering Chemistry, Vol. 5, page 377, 1913) refers to some tests made by the United States Forest Service, using the well-known fungus causing the disease of coniferous trees (*Polyporus annosus*), and from a series of tests he reaches certain conclusions as to the antiseptic value of different constituents of creosote oil. So far as known to the writers, the fungus used never caused a decay of structural timber. This fungus is strictly

confined to the root system of living trees, and it can hardly be taken as a fair representative of the fungi which cause decay of structural timber.

Another series of cultural experiments is reported by Dean & Downs before the Eighth International Congress of Applied Chemistry, using *Polystictus versicolor*. These experiments were made largely with reference to the comparison of creosote and water gas creosote, although they state that "the greater value of the coal-tar oil appears to depend upon the presence of the tar acids and especially upon the tar bases." They do not report any specific results with reference to the effect of different portions of creosote oil other than the quotation made.

Ignoring for the time being the more or less inconclusive nature of the investigations referred to, most of which appear to indicate that coal-tar acids are chiefly effective in causing timber to last (J. M. Weiss regards the lower-boiling coal-tar oils as distinctly more antiseptic than the higher boiling ones), one should turn to an examination of creosoted timbers which have actually lasted. In Bulletin No. 93, 1907, a table was presented showing the nature of the oils extracted from old creosoted timbers. Reference to this table will show that in all cases where timbers have been exposed to the air for a considerable period of time, the percentage of oils distilling below 235 degrees Centigrade is extremely small. The older the timber, the more striking is this disappearance. Coincident with this is the finding that the oils remaining in all of these timbers show a very high percentage of high-boiling compounds, that is, oils distilling above 315 degrees Centigrade. All of the timbers referred to in this table were still in an excellent state of preservation, so far as fungus attack is concerned, and the recent examination of many of them shows that they are still in a good state of preservation.

Reference to a paper published by G. Alleman (Forest Service Circular No. 98, 1907) shows the same condition just referred to, that is, the major part of the oils extracted from old timbers consist of high-boiling compounds.

In a recent paper on oils extracted from old piles, by E. Bateman (Forest Service Circular No. 199), statement is made that "practically no light oils were found in the piles after their long period of service (30 years). If originally present, they were lost by volatilization and leaching."

In a recent bulletin, Mr. Teasdale (Forest Service Circular No. 188) presents the results on the volatilization of various fractions of creosote oil after their injection into wood. His conclusions were as follows:

"It may be inferred that a creosote to be of the most value, at least for treating loblolly pine, should contain considerable quantities of high-boiling fractions, which appear to block up the outer cells and so insure the retention of the lighter oils in the interior of the wood."

Irrespective of the laboratory determinations, it seems to be an actual fact that the low-boiling oils injected into the timber disappear from the wood within a comparatively short period of time. The writers do not think that it is an exaggeration when it is stated that probably most

of the low-boiling oils disappear in ten or twelve years, and in many cases probably sooner. In the case of the creosoted telephone poles referred to in Bulletin No. 93, the low-boiling oils had disappeared in nine years. It appears, therefore, that there is only one conclusion which can be drawn from the numerous data developed during recent years, and that is that the heavy oil constituents, irrespective of what they may be considered chemically, are actually preserving the wood.

Referring to some of the old timbers in detail, the percentage of oils distilling above 315 degrees Centigrade are as follows:

	Per cent.
L. & N. piles, West Pascagoula, Ala., 28 years' service	49.03
Muskogee Wharf, Pensacola, Fla., 23 years' service	54.75
Galveston Bay Bridge, Santa Fe System, 28 years' service	50.01
River Nene, England, 51 years	66.80
Galveston Bay Bridge, Santa Fe System, 28 years' service	59.88
Galveston Bay Bridge, Santa Fe System, 28 years' service	56.34
Railroad tie, Great Western Railroad, England, 24 years' service	71.5
Railroad tie, Great Western Railroad, England, 24 years' service	79.49
New Orleans paving block, 35 years, etc., etc.	66.3

These timbers, as stated above, are in an excellent state of preservation, and there is no indication that they are beginning to decay. The oils contained in all of the timbers quoted consist of more than 50 per cent. distilling above 315 degrees. It is, of course, impossible to say that these are in any way active in preserving the timber. It may be that the portions of the oil distilling below 315 degrees are the really effective agents in preserving the wood. Nevertheless, the fact remains that in the older timbers, which are perfectly sound, a very large percentage of the oil still in the wood is composed of the heaviest portions of creosote oil. It should be taken into consideration in any problem involving the question as to what parts of creosote are most effective in preventing decay, that long-term tests after all are more indicative as to what may be expected of the timber preservative than any laboratory test, which, however valuable it may be, must always be considered as indicative rather than a final proof.

Applying this discussion to the question of mixing a certain percentage of coal-tar with low-boiling creosote oil, it is not unreasonable to assume that by adding heavier compounds to a low-boiling oil, the permanence of this oil is thereby increased. No proof has yet been submitted which would indicate that the addition of these heavier compounds in any way reduced the antiseptic value of the creosote oil itself. On the contrary, it may materially aid in increasing the antiseptic value by the addition of compounds which will remain in the wood in a more or less permanent manner.

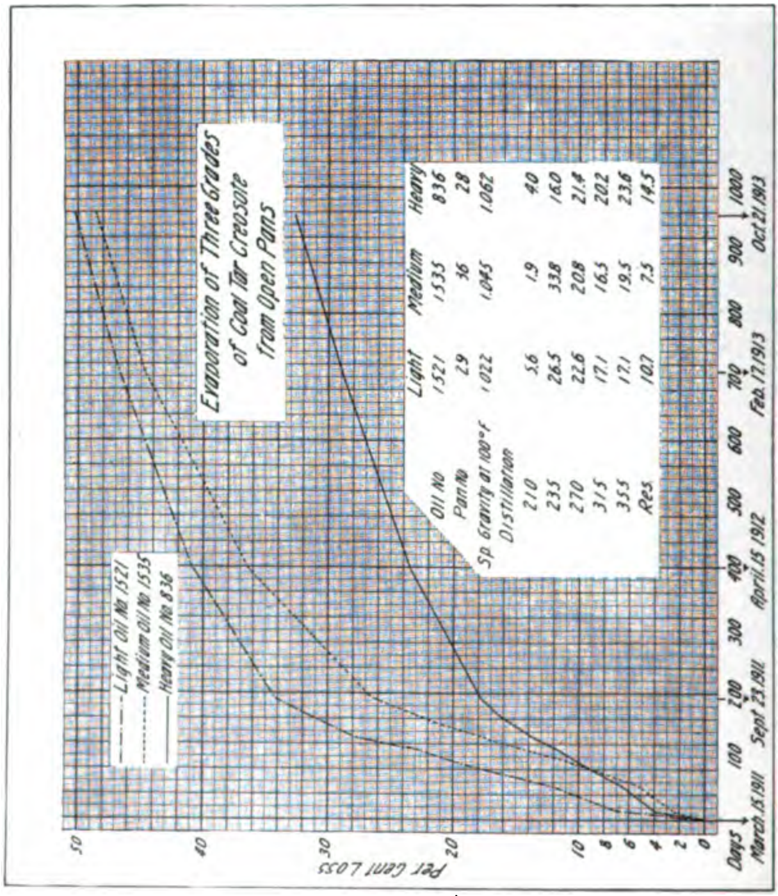

Evaporation of Three Grades of Coal Tar Creosote from Open Pans
Light Oil No. 1521
Medium Oil No. 1535
Heavy Oil No. 836
Light Medium Heavy
Oil No 1521 1535 836
Pan No 29 36 28
Sp. Gravity at 100° F 1.022 1.045 1.062
Distillation
210 5.6 1.9 4.0
235 26.5 33.8 16.0
270 22.6 20.8 21.4
315 17.1 16.5 20.2
355 17.1 19.5 23.6
Res. 10.7 7.5 14.5
Per Cent Loss
50 40 30 20 10 8 6 4 2 0
Days 100 200 300 400 500 600 700 800 900 1000
March 15.1911
Sept 23.1911
April 15 1912
Feb. 17.1913
Oct 21.1913
Chart No. 1.

CHART NO. 2.

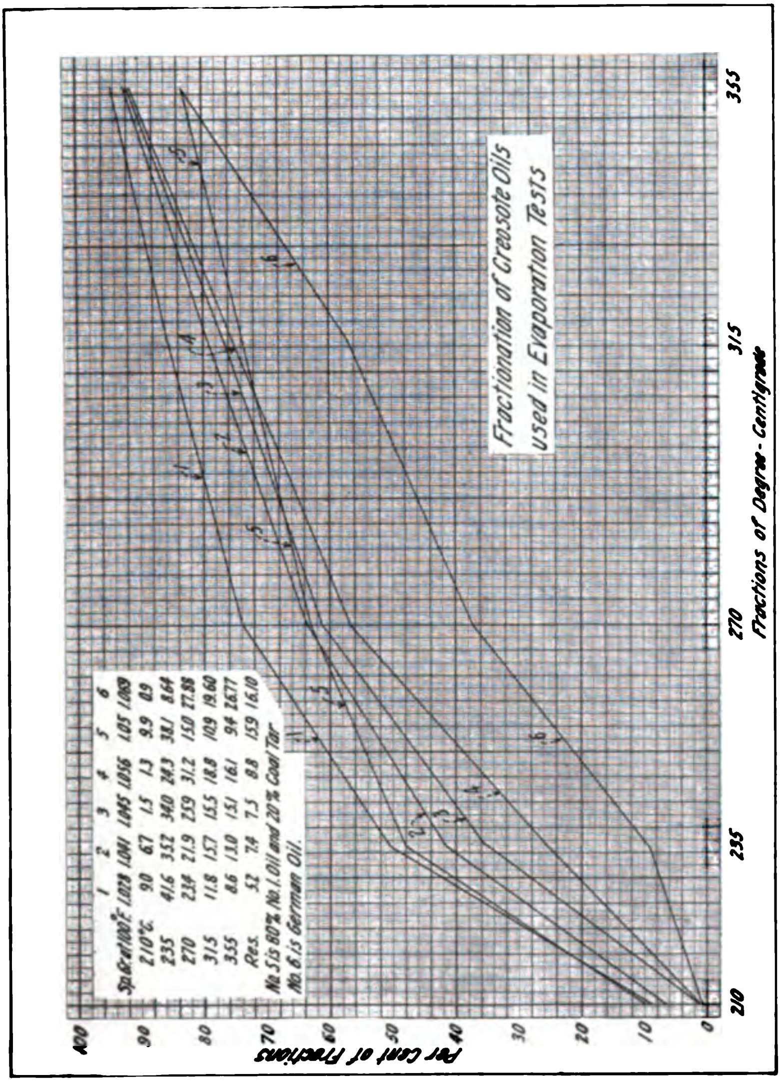

Fractionation of Creosote Oils used in Evaporation Tests
1 2 3 4 5 6
Sp.Gr.at 100°F. 1.028 1.041 1.045 1.056 1.05 1.069
210°C. 9.0 6.7 1.5 1.3 9.9 0.9
235 41.6 35.2 34.0 24.3 38.1 8.64
270 23.4 21.9 25.9 31.2 15.0 27.98
315 11.8 15.7 15.5 18.8 10.9 19.60
355 8.6 13.0 15.1 16.1 9.4 26.77
Res. 5.2 7.4 7.5 8.8 15.9 16.10
No. 5 is 80% No. 1. Oil and 20% Coal Tar
No. 6 is German Oil.
Per Cent of Fractions
0 10 20 30 40 50 60 70 80 90 100
210 235 270 315 355
Fractions of Degree - Centigrade

CHART No. 3.

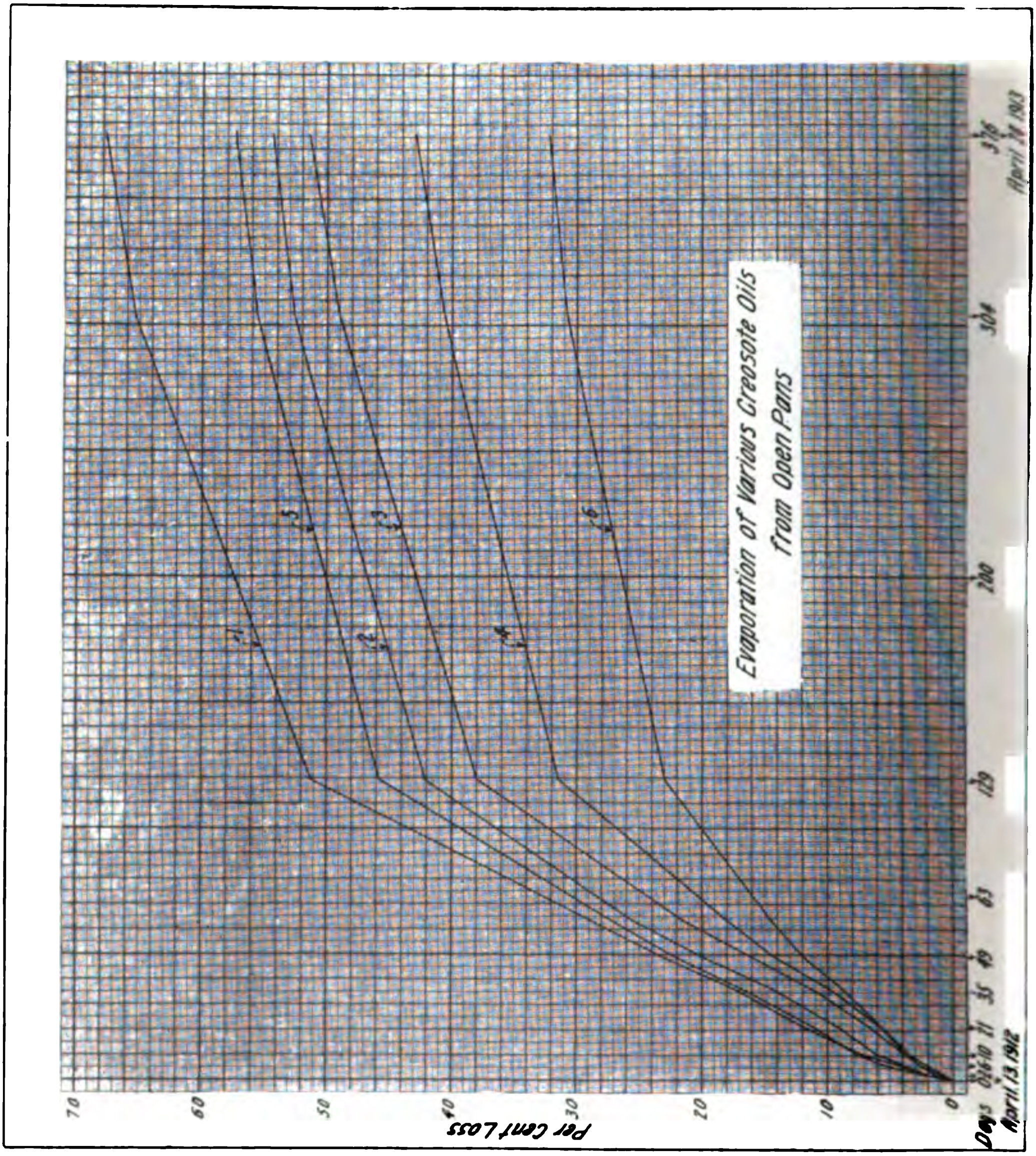

Evaporation of Various Creosote Oils
from Open Pans
Per Cent Loss
70
60
50
40
30
20
10
0
Days
April 13, 1912
35
49
63
129
200
304
376
1
2
3
4
5
6

CHART No. 4.

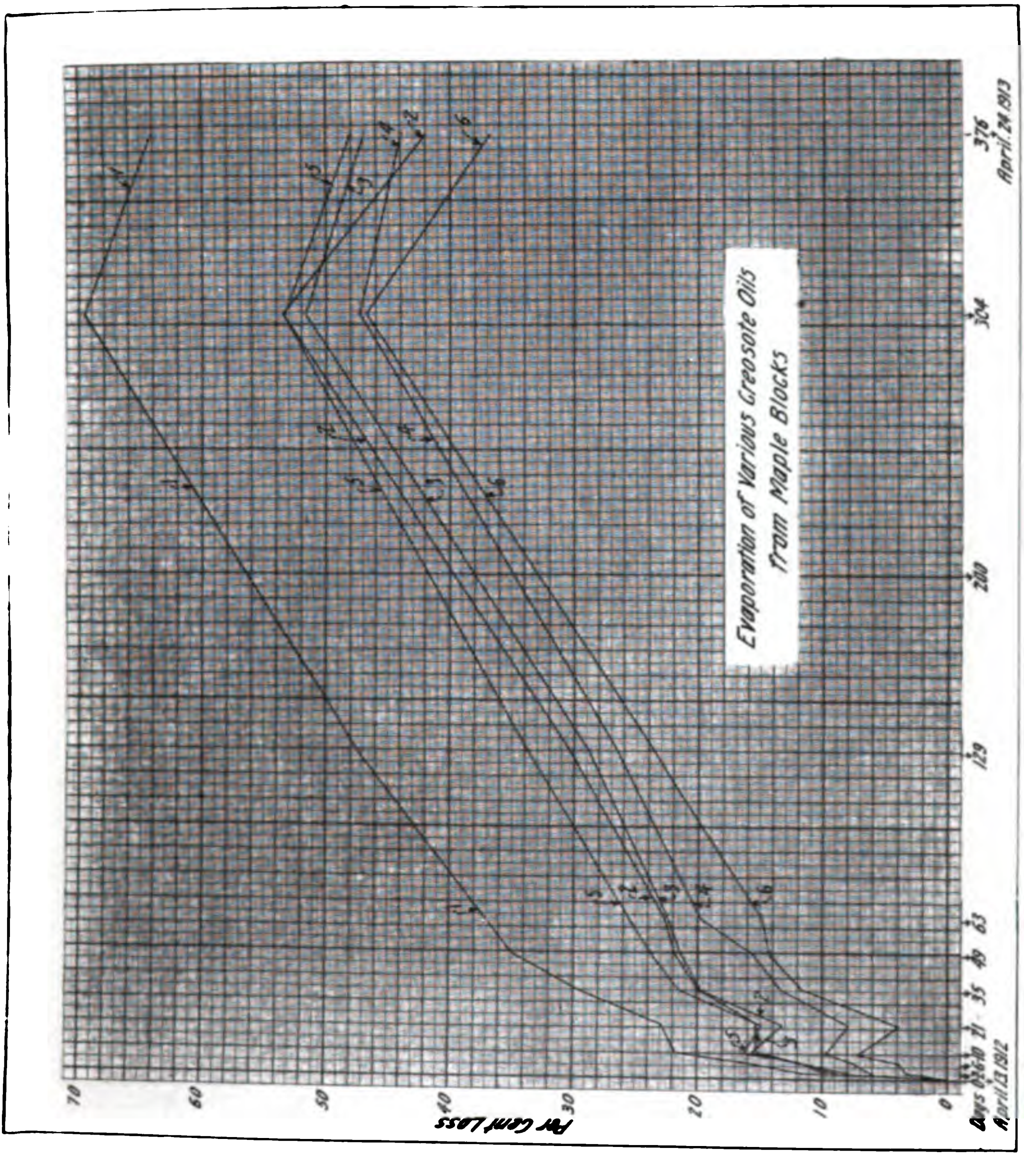

Evaporation of Various Creosote Oils
from Maple Blocks
Per Cent Loss
0
10
20
30
40
50
60
70
Days 0 3 6 10 21 35 49 63 129 200 304 376
April 13 1912
April 24 1913

Chart No. 5.

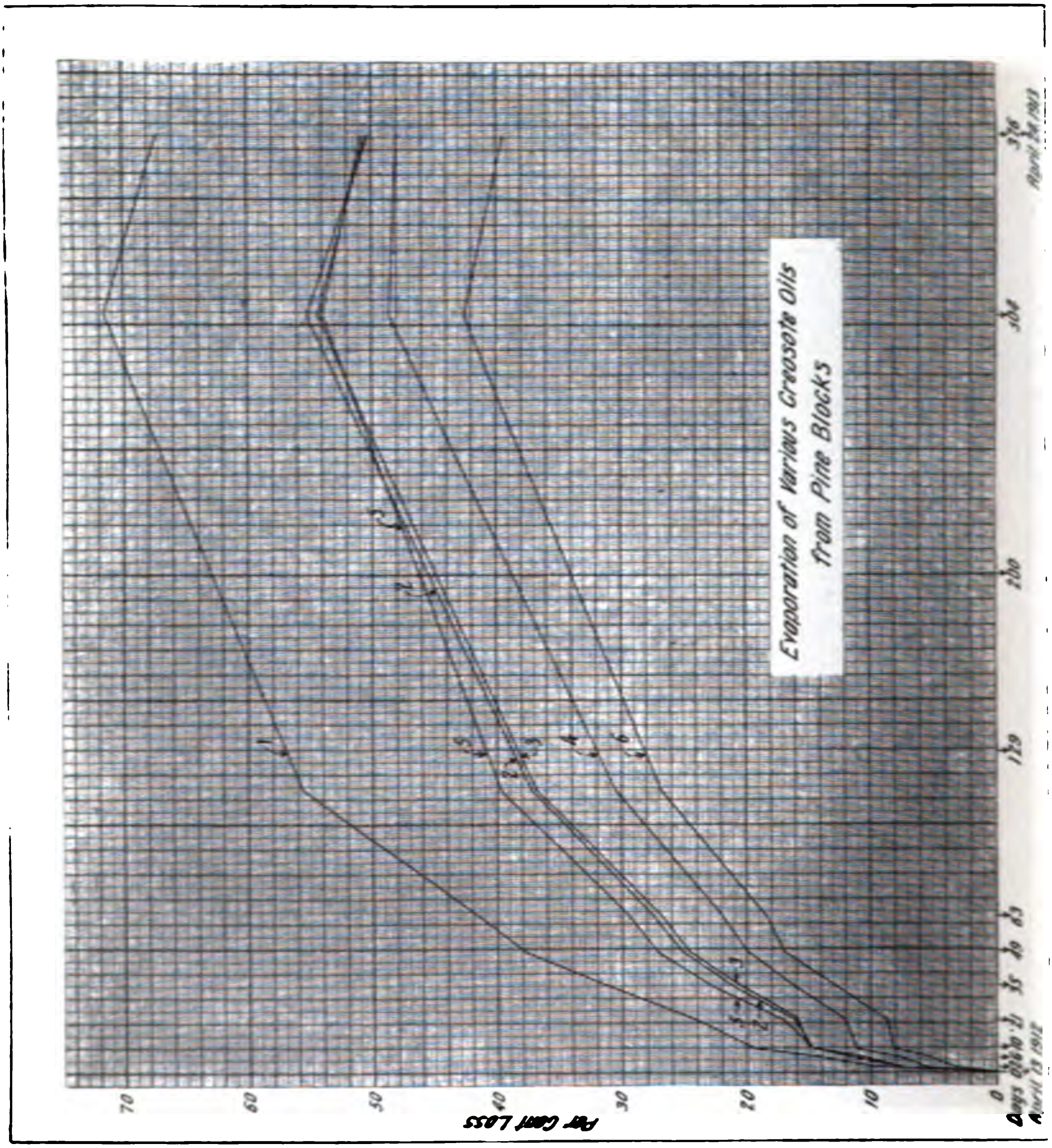

Evaporation of Various Creosote Oils
from Pine Blocks
Per Cent Loss
Days
0
10
20
30
40
50
60
70
129
200
304
376

CHART NO. 6.

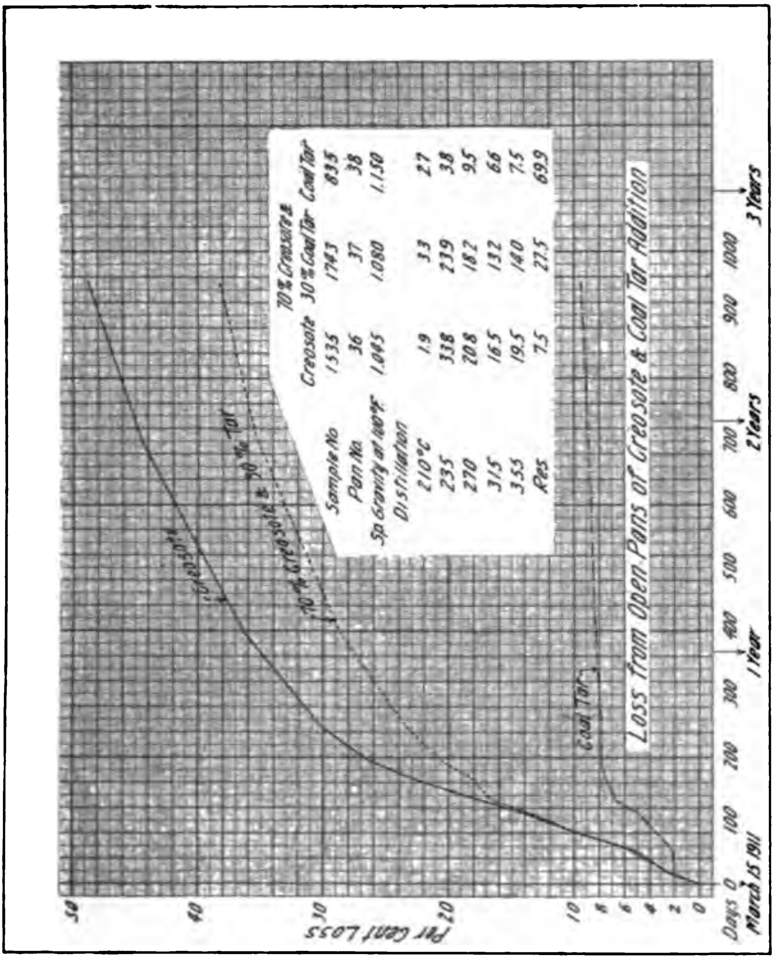

Loss from Open-Pans of Creosote & Coal Tar Addition
Per Cent Loss
Creosote
70% Creosote & 30% Tar
Coal Tar
Days
March 15 1911
1 Year
2 Years
3 Years
Creosote | 70% Creosote & 30% Coal Tar | Coal Tar
Sample No 1535 1743 835
Pan No 36 37 38
Sp Gravity at 100°F 1.045 1.080 1.150
Distillation
210°C 1.9 3.3 2.7
235 33.8 23.9 3.8
270 20.8 18.2 9.5
315 16.5 13.2 6.6
355 19.5 14.0 7.5
Res 7.5 27.5 69.9

Chart No. 7.

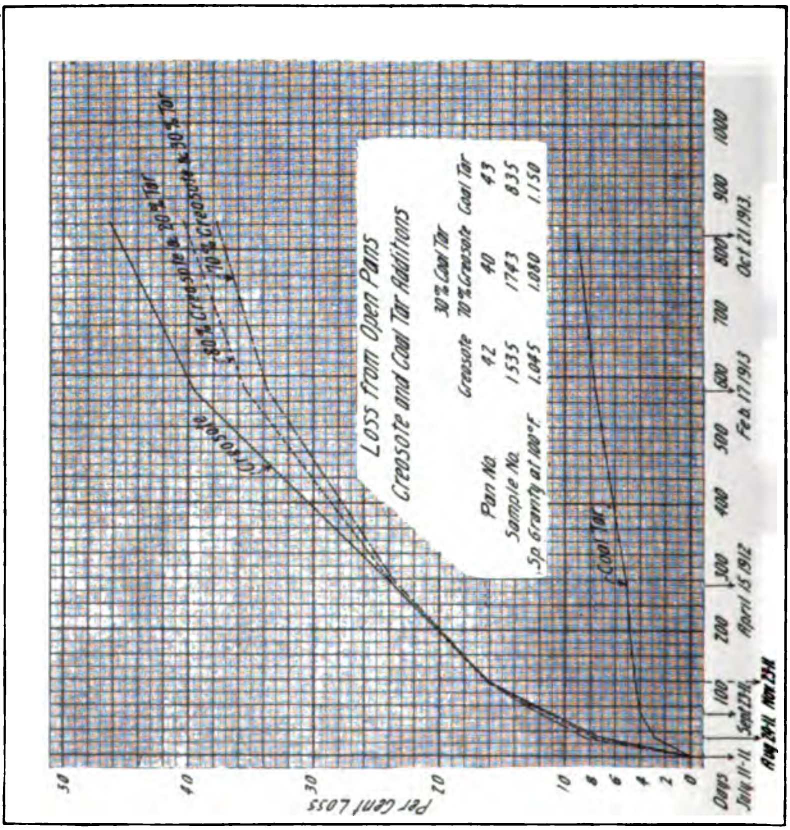

Loss from Open Pans
Creosote and Coal Tar Additions
Creosote
30% Coal Tar 70% Creosote
Coal Tar
Pan No. 42 40 43
Sample No. 1535 1743 835
Sp. Gravity at 100°F. 1.045 1.080 1.150
Creosote
80% Creosote & 20% Tar
70% Creosote & 30% Tar
Coal Tar
Per Cent Loss
0 2 4 6 8 10 20 30 40 50
Days
0 100 200 300 400 500 600 700 800 900 1000
July 11-11
Aug 29-11
Sept 27-11
Nov 25-11
April 15 1912
Feb. 17 1913
Oct 21 1913

Chart No. 8.

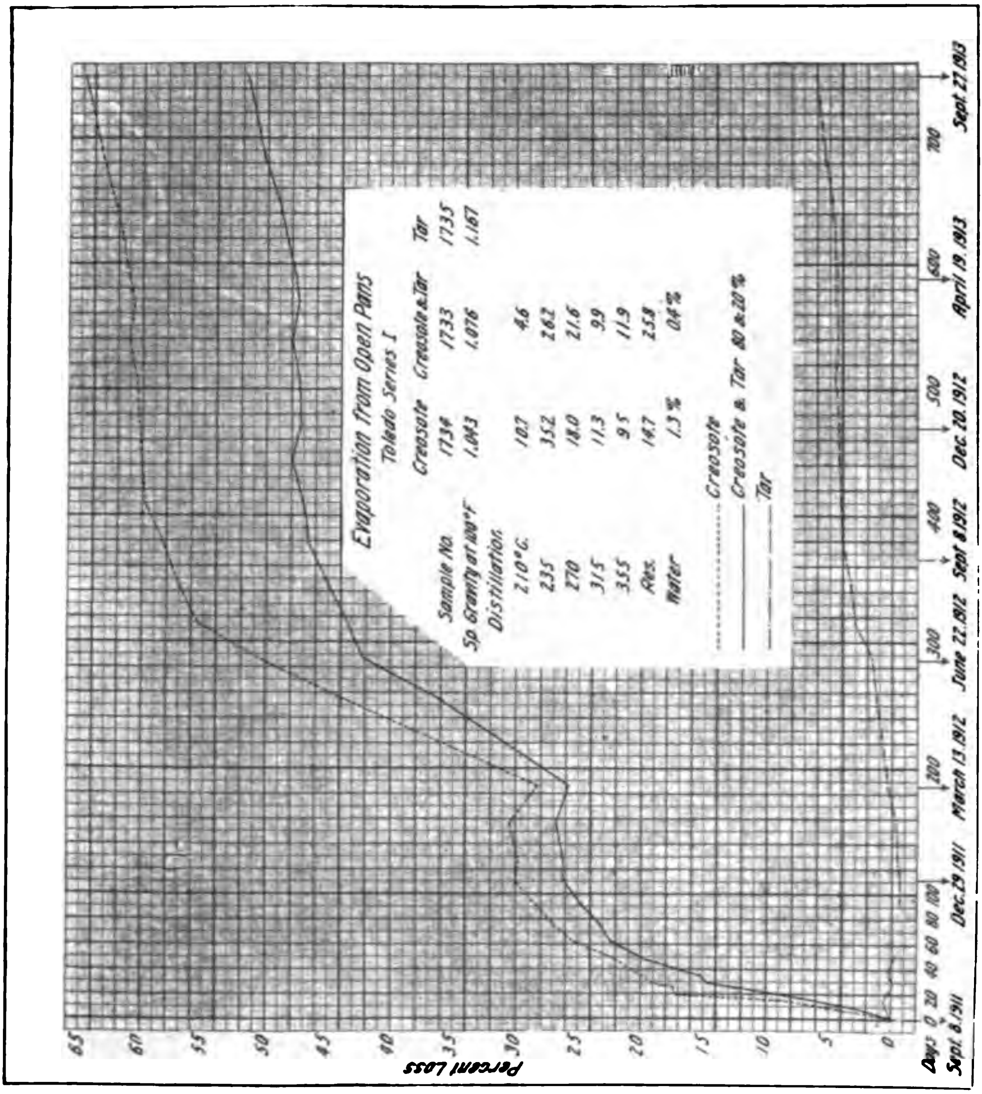

Evaporation from Open Pans
Toledo Series I
Creosote | Creosote & Tar | Tar
Sample No. | 1734 | 1733 | 1735
Sp. Gravity at 100°F | 1.043 | 1.076 | 1.167
Distillation
210°C. | 10.7 | 4.6
235 | 35.2 | 26.2
270 | 18.0 | 21.6
315 | 11.3 | 9.9
355 | 9.5 | 11.9
Res. | 14.7 | 25.8
Water | 1.3% | 0.4%
Creosote
Creosote & Tar 80 & 20%
Tar
Percent Loss
0 5 10 15 20 25 30 35 40 45 50 55 60 65
Days 0 20 40 60 80 100 200 300 400 500 600 700
Sept. 8.1911
Dec. 29.1911
March 13.1912
June 22.1912
Sept. 8.1912
Dec. 20.1912
April 19.1913
Sept. 27.1913

CHART No. 9.

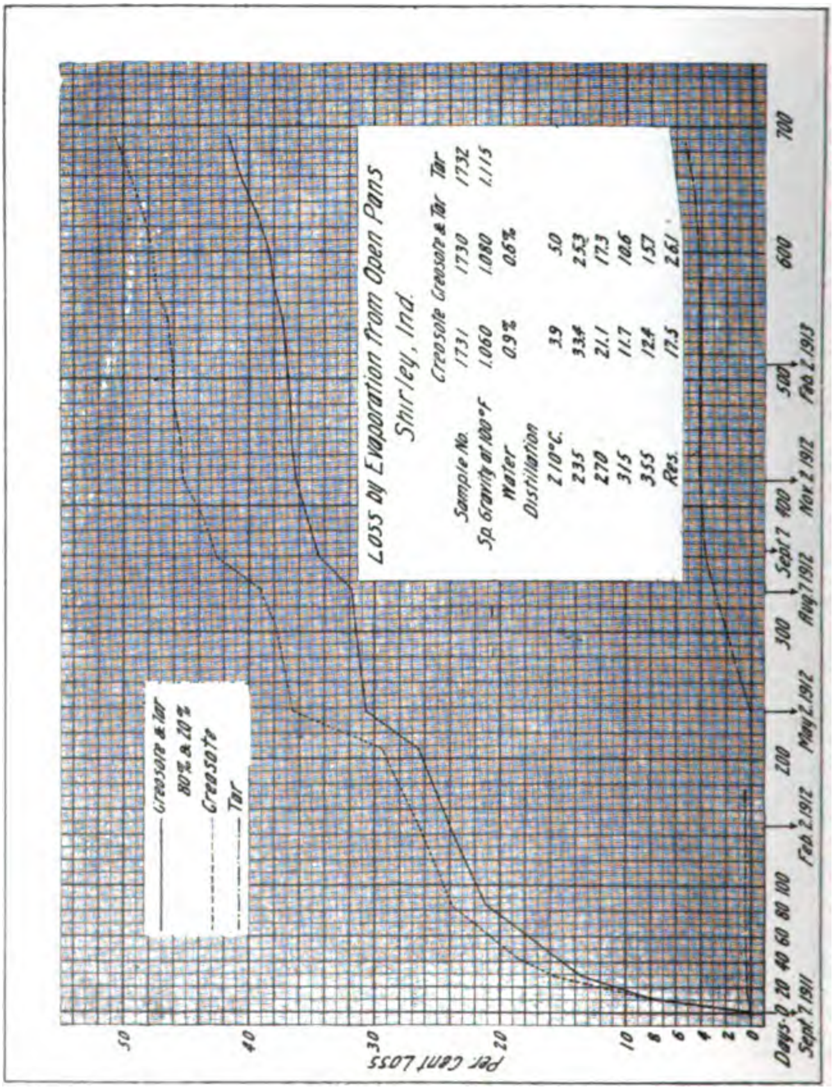

Loss by Evaporation from Open Pans
Shirley, Ind.
Creosote Creosote & Tar Tar
Sample No. 1731 1730 1732
Sp. Gravity at 100°F 1.060 1.080 1.115
Water 0.9% 0.6%
Distillation
210°C. 3.9 5.0
235 33.4 25.3
270 21.1 17.3
315 11.7 10.6
355 12.4 15.7
Res. 17.5 26.1
Creosote & Tar 80% & 20%
Creosote
Tar
Per Cent Loss
50
40
30
20
10
8
6
4
2
0
Days-0 20 40 60 80 100 200 300 400 500 600 700
Sept 7 1911
Feb 2 1912
May 2 1912
Aug 7 1912
Sept 7
Nov 2 1912
Feb 2 1913

CHART No. 10.

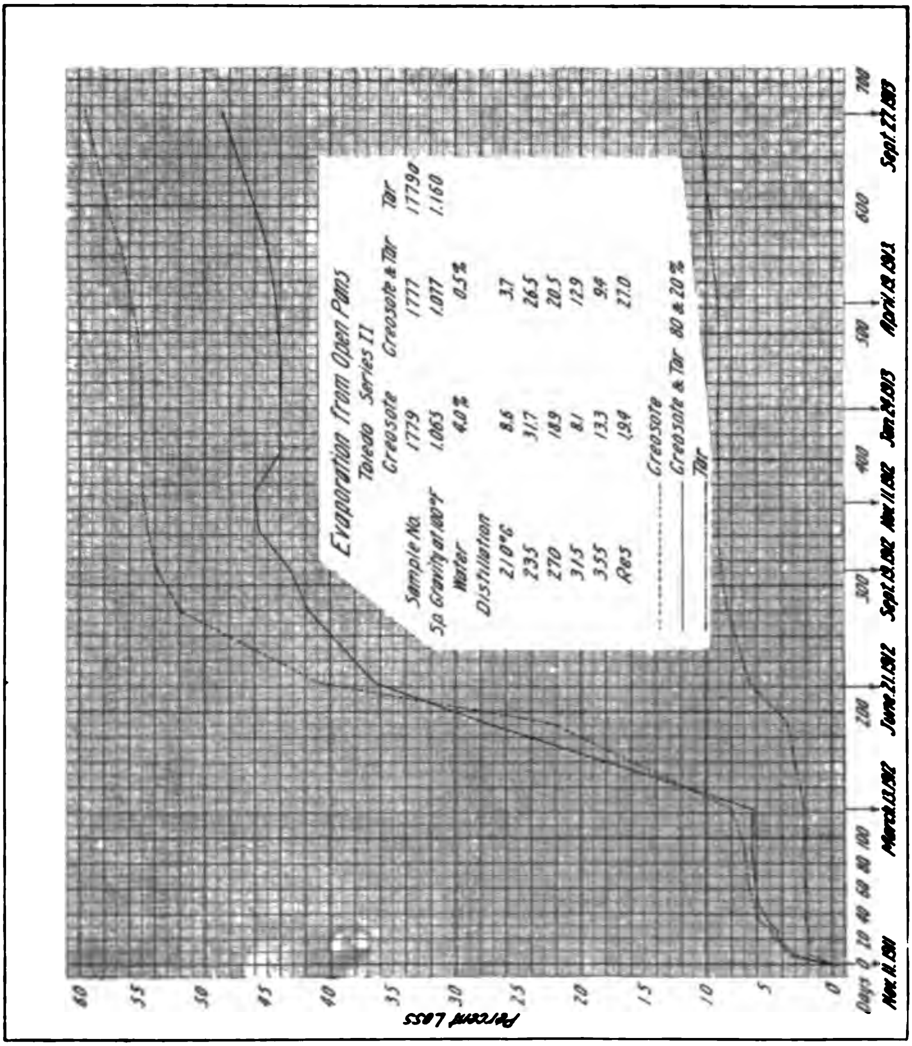
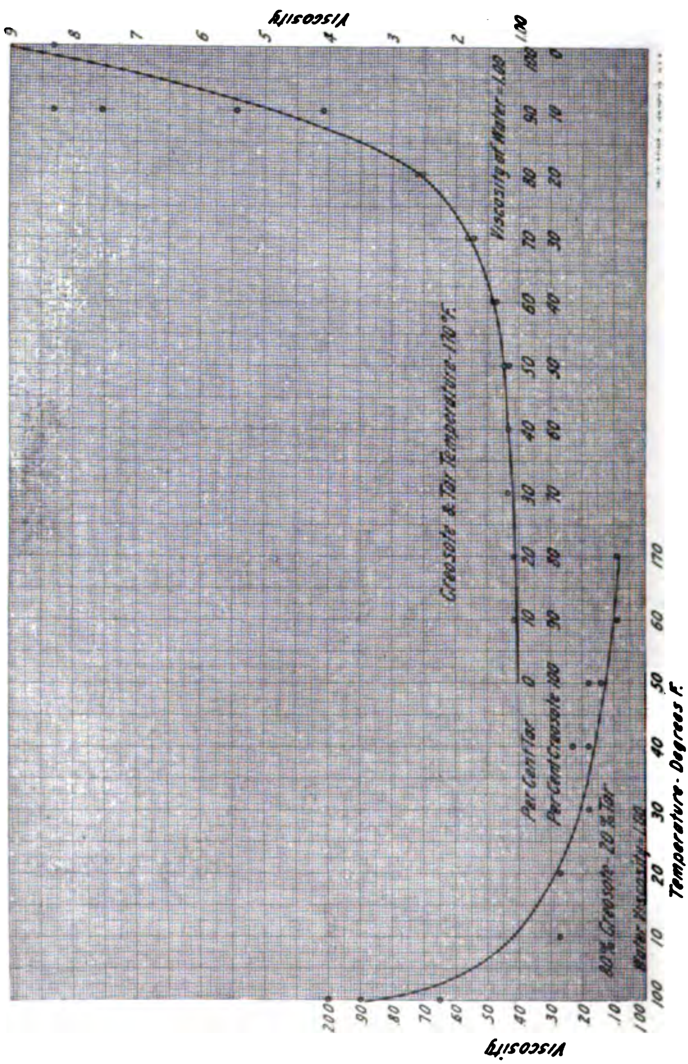

Evaporation from Open Pans
Toledo Series II
Creosote Creosote & Tar Tar
Sample No. 1779 1777 1779a
Sp. Gravity at 100°F 1.063 1.077 1.160
Water 4.0% 0.5%
Distillation
210°C 8.6 3.7
235 31.7 26.5
270 18.9 20.5
315 8.1 12.9
355 13.3 9.4
Res. 19.4 27.0
Creosote
Creosote & Tar 80 & 20%
Tar
Percent Loss
Days 0 20 40 60 80 100 200 300 400 500 600 700
Nov. 11.1911 March 13.1912 June 21.1912 Sept. 19.1912 Nov. 11.1912 Jan. 29.1913 April 19.1913 Sept. 27.1913

CHART No. 11.


Viscosity
Creosote & Tar Temperature-170°F.
Viscosity of Water-1.00
Per Cent Tar
Per Cent Creosote
80% Creosote-20% Tar
Temperature-Degrees F.
Viscosity

The foregoing conclusion was reached many years ago (1884) by Mr. Boulton in his famous treatise on "The Antiseptic Treatment of Timber." Quoting from Mr. Boulton:

"Sleepers were also received from the Taff Vale Railway, the South-Eastern Railway, and the Great Eastern Railway, which had been in use for periods varying from 14 to 23 years. A portion was also taken from a creosoted pale fence, which had been fixed in the Victoria docks in 1855, and which is still in place, perfectly sound and strong, after 29 years' use. A careful analysis of these seventeen specimens, all of ordinary Baltic fir, gave the following results:

"(1) In no case were any tar acids detected by the ordinary tests.

"(2) In fourteen out of the seventeen specimens the semi-solid constituents of the tar oils were present; in twelve of them was naphthalene, this body being in some cases in considerable quantity.

"(3) Only small percentages remained of oils distilling below 450 degrees Fahrenheit. In the majority of instances from 60 per cent. to 75 per cent. of the total bulk of substances retained in the wood did not distill until after a temperature of 600 degrees Fahrenheit (315 degrees Centigrade) was reached.

"It is clear, therefore, that these timbers had been preserved by the action of the heaviest and most solid portions of the tar oils and that the other constituents had disappeared."

RELATION OF PENETRATION.

Successful creosoting will always depend very largely upon the penetration secured. In other words, no timber can be considered as well-creosoted unless all sapwood is thoroughly penetrated in timbers which have an impenetrable heartwood, like pine, beech, etc., and unless complete penetration is obtained throughout the piece in timbers which have a penetrable heartwood, like some species of red oak. No criterion has been established to show relative penetration of different compounds. So far as is known to the writers, it will be almost impossible to establish a positive criterion, because the inherent variability of the wood fiber is so great that no two sticks can be found, which, if tested even under the same conditions of temperature and pressure, will permit making comparative tests as to the penetrating power of several liquids and obtain absolute results. The best that can be done is to select pieces from the same stick of wood and compare these by using different preservatives. The same piece will, however, show variations using the same liquid (see plates 1 and 2). The writers have made a good many tests of conditions governing the penetrability of creosote oils, and as a result of these tests, believe that there are certain fundamental conditions which either favor or retard penetration. These are briefly as follows:

1. The presence or absence of a certain percentage of moisture.
2. The viscosity of the oil.
3. The character of the wood fiber to be penetrated; that is, its density and the condition of the walls are important factors.
4. The presence or absence of solid matter in the impregnating liquid.

Moisture acts as a retardent, and the highest penetration will be obtained where the smallest amount of water is found in the wood structure. It is hardly necessary to give any detailed facts to substantiate this conclusion. It has been thoroughly demonstrated on a practical scale at treating plants all over the world that dry wood can be penetrated throughout, whereas green wood cannot be penetrated.*

The relation between viscosity and penetration has been well put by Weiss (Journal of Industrial and Engineering Chemistry, Vol. 5, page 378); "The depth to which oils can be impregnated varies as some inverse function of the viscosity."

In the writers' experience the relation between viscosity and penetration will hold almost universally for liquids of various types. It is exceedingly difficult to prove this, as has been stated, because it is hardly ever possible to completely eliminate the variable in the wood fiber. It can be approximated, however, by using a considerable number of pieces, using pieces of the same stick for different oils. Where this is carefully done and where every possible factor of moisture, density of wood fiber, etc., has been eliminated, the degree of penetration will increase as the viscosity decreases. Viscosity tests were made with creosote and with the same creosote to which a certain per cent. of coal-tar had been added. It was found that the viscosity of the mixture composed of 80 per cent. creosote oil and 20 per cent. coal-tar was approximately equivalent to the viscosity of the creosote oil when both were measured at a temperature of 170 degrees Fahrenheit. On chart No. 11 the specific viscosity of different percentages of coal-tar and creosote combinations are shown, and also a curve showing the specific viscosity of 80 per cent. creosote oil and 20 per cent. coal-tar at different temperatures. It will be noted that as the temperature approaches the working temperature in the creosoting cylinders (usually between 180 and 190 degrees Fahrenheit), the viscosity of the mixture is practically that of the creosote oil without any tar addition. Judging from this, therefore, the penetration of the coal-tar-creosote mixture, in the proportion of 80 per cent. creosote oil and 20 per cent. coal-tar, will be about the same as that of the creosote oil.

In order to obtain some graphic method for determining the extent of penetration which can be obtained with various liquids under approximately the same conditions, the writers made a series of tests extending over a period of several years. It was finally found that comparative results could be obtained by using comparatively large-sized pieces of wood and allowing the liquids to be tested to seep into the wood longitudinally. The method of testing finally adopted will be best illustrated by the description of the last series made.

Four average air-dried loblolly pine ties were selected. These ties were strictly average ties. The only special precaution taken in their selection was to pick out ties with a minimum number of season checks.

*Bailey, I. W.: The Preservative Treatment of Wood, Forestry Quarterly, March 1913.

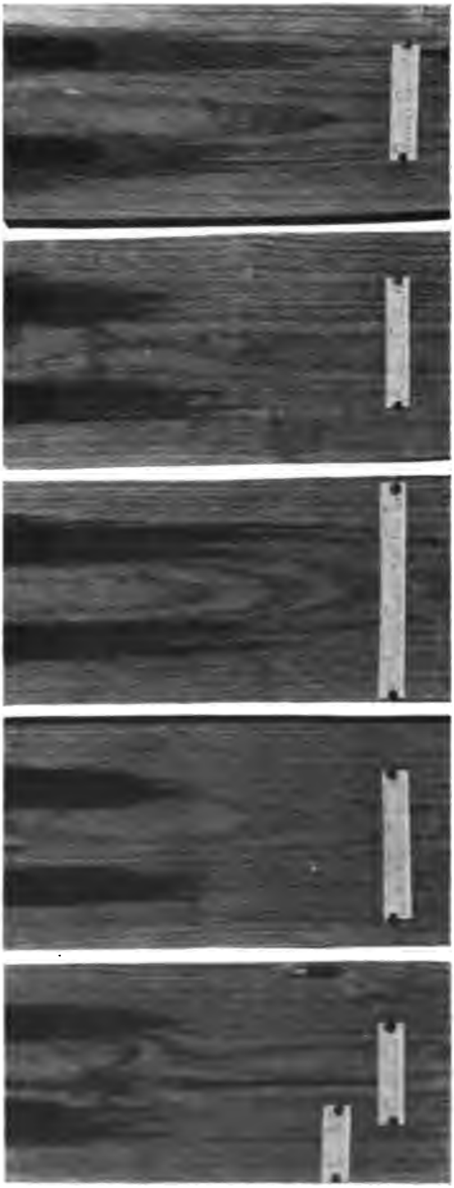
The four ties selected may be regarded as typical ties, such as are being treated every day. Each tie was sawed into five pieces, the lengths being approximately equal. After sawing, the pieces were placed into a warm place so as to become warmed through. Two holes were then bored into the end of each piece. These holes were bored to a depth of four inches as nearly as possible. The pieces were then returned to the warm place. In the first series five different preservatives were used: a good German creosote oil, a light American creosote, a mixture of 80 per cent. light American creosote and 20 per cent. coal-tar (containing 7 per cent. free carbon), a heavy carbolineum, and a sample of Lyster wood preservative. Piece No. 1 was selected for the German creosote, piece No. 2 for the American creosote, etc. Using piece No. 1 as an example, 80 c.c. of German creosote were poured into each of the two holes. In the same manner 80 c.c. of American creosote were poured into each of the two holes of the second piece, and so on for the other pieces. The pieces were then put in a warm place in the cylinder house until there was no evidence of liquid in the holes. This procedure was carried out with all four ties. Some three weeks after the last oil had disappeared, the pieces were sawed longitudinally through the holes and photographed. These photographs are reproduced on plates Nos. 1 and 2.

The analyses of the preservatives used in this penetration test are given in the following table:

	German Creosote.	Carbolineum.	American Creosote.	Lyster Wood Creosote.	80 and 20 per cent. Mixture.
Sp. Gr. at 100° F.	1.0642	1.1026	1.0336	1.0901	1.0699
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Tar Acids by Volume	7.0	4.0	8.5	75.0	6.75
Up to 200° C.	0.1	0.0	1.7	1.2	0.0
200 to 210	1.5	0.0	5.2	0.5	0.6
210 to 235	9.5	0.0	35.6	9.1	26.7
235 to 270	21.3	0.1	23.3	44.1	26.2
270 to 315	23.9	13.2	12.7	30.9	12.4
315 to 355	23.6	48.5	12.0	2.7	12.8
Residue	19.9	37.8	9.3	10.3	21.2
Water	0.0	0.0	0.0	1.1	0.0

Referring to the photographs, it will be noted that the oils penetrated the wood fiber around the holes to a small extent, but that the principal penetration was downward from the holes. It will furthermore be noted that even in the same piece there is a slight variation, due possibly to the difference in the nature of the fibers in that particular piece. The American creosote had such a high percentage of naphthalene that some of it solidified, even in the heated room, hence the penetration recorded for this oil is more or less defective. In the other four cases, however, every trace of oil had disappeared from the holes. A careful comparison of the four series shows that the combination of the 80

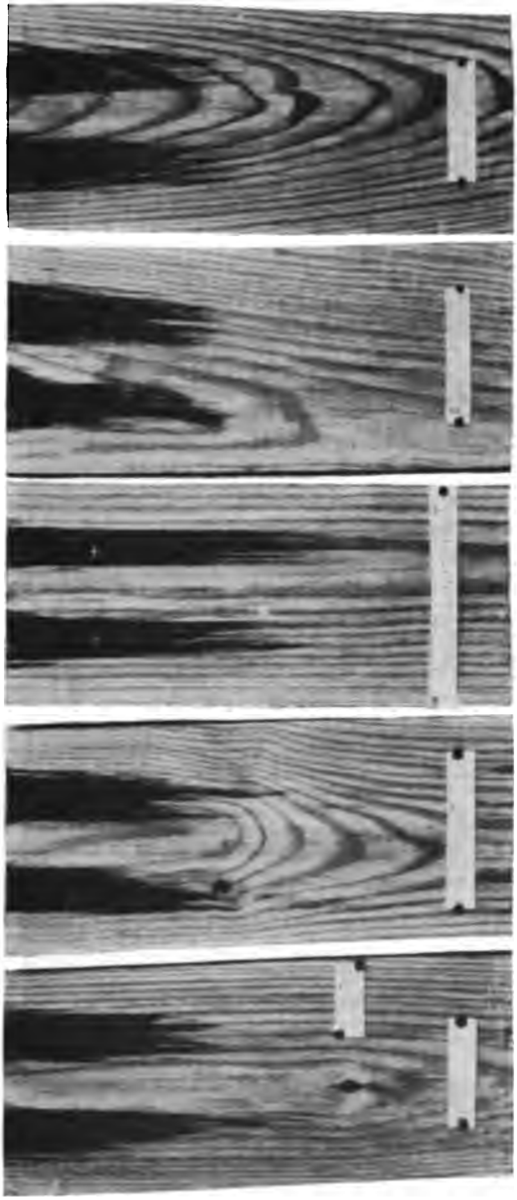
PLATE I.



SERIES "A S."

German Creosote. American Creosote. Creosote and Tar. Lyster. Carbolineum.

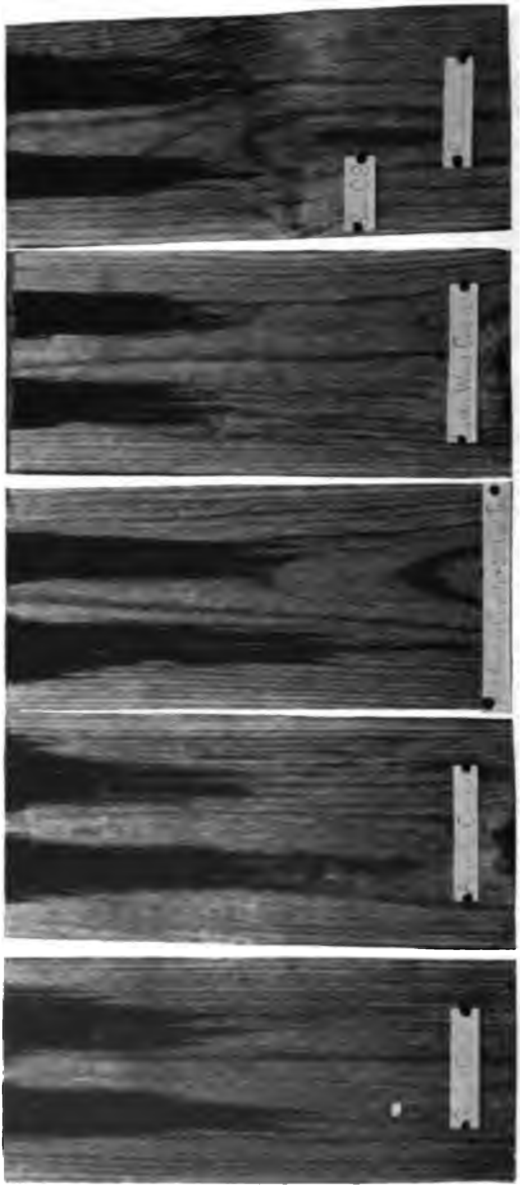
PLATE I.



German Creosote. American Creosote. Creosote and Tar. Lyster. Carbolineum.

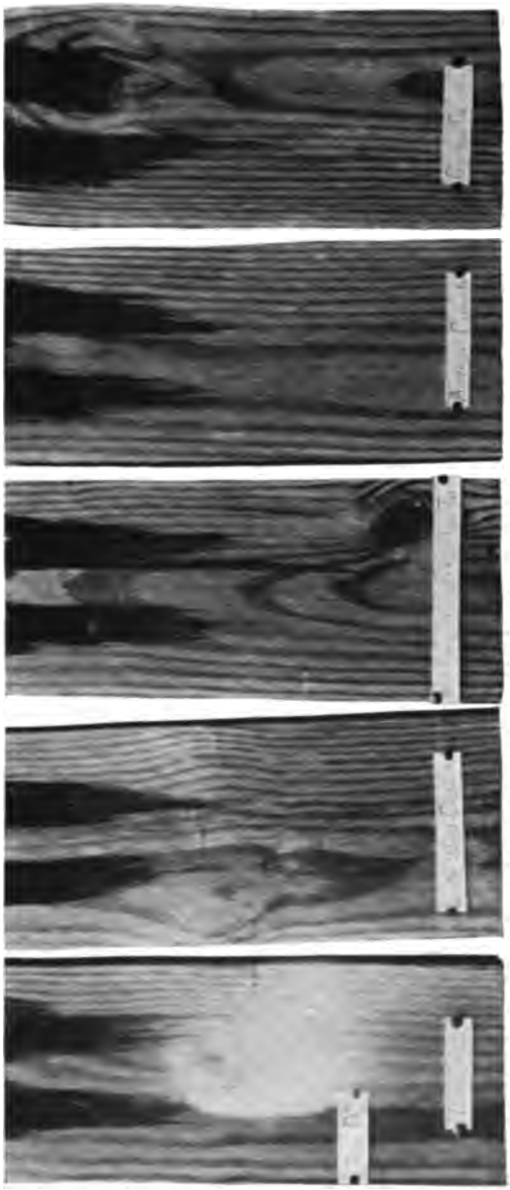
SERIES "B S."

PLATE II.



German Creosote. American Creosote. SERIES "C S." Creosote and Tar. Lyster. Carbolineum.

PLATE II.



German Creosote.

American Creosote.

SERIES "D S."

Creosote and Tar.

Lyster.

Carbolineum.

PLATE III.

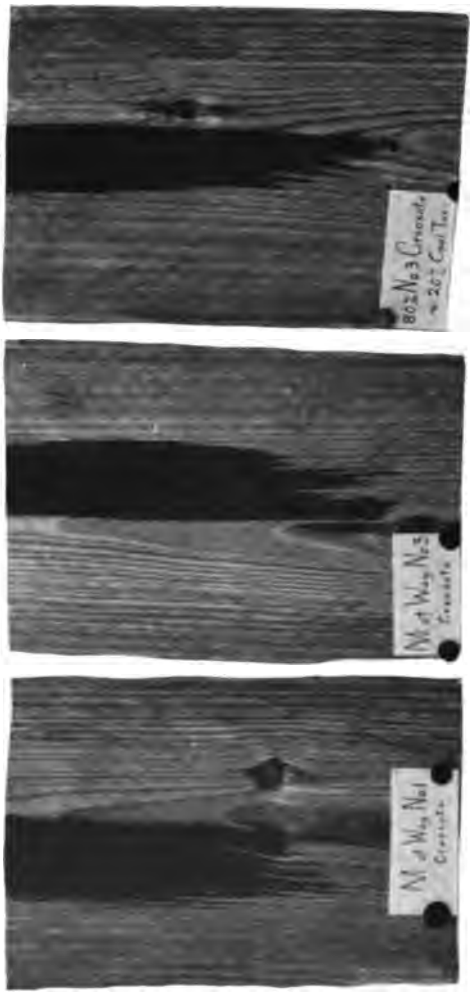

80% No3 Creosote
+ 20% Coal Tar
M of Way No 3
Creosote
M of Way No 1
Creosote

PLATE IV.

No. 6447—Mixture.
Tie Weight, 135.5 lbs.
Absorption, 15.5 lbs.

No. 6560—Creosote.
Tie Weight, 136 lbs.
Absorption, 14 lbs.

PLATE IV.

No. 6408—Mixture.
Tie Weight, 124.5 lbs.
Absorption, 21.0 lbs.

No. 6525—Creosote.
Tie Weight, 121.5 lbs.
Absorption, 20.0 lbs.

PLATE V.

Creosote.
Weight, 132 lbs.
Absorption, 25.5 lbs.

Creosote and Tar.
Weight, 139.5 lbs.
Absorption, 23 lbs.

PLATE V.

No. 6418—Mixture.
Tie Weight, 149.5 lbs.
Absorption, 14.5 lbs.

No. 6532—Creosote.
Tie Weight, 145.0 lbs.
Absorption, 27.0 lbs.

PLATE VI.

Creosote.
Weight, 126 lbs.
Absorption, 14 lbs.

Creosote and Tar.
Weight, 126 lbs.
Absorption, 111 lbs.

PLATE VI.

Creosote.
Weight, 117 lbs.
Absorption, 13 lbs.

Creosote and Tar.
Weight, 113 lbs.
Absorption, 13.5 lbs.

per cent. creosote oil and 20 per cent. coal-tar penetrated as far into the wood as did the German creosote; in fact, in some cases the penetration appears to be somewhat better. It certainly exceeded the penetration obtained with the Lyster wood preservative and that obtained with the carbolineum, for both of which compounds exceedingly high penetrating powers are claimed. Attention is called to the fact that the penetration shown in the four test pieces was relatively about the same for all the compounds, although the actual penetration, that is, the number of inches, varies somewhat in the different series. This was due no doubt to the fact that the different ties had different degrees of moisture. Series D. S. had a particularly high water content in the wood fiber, hence a smaller penetration.

The writers believe that this type of test shows in a much fairer way what can be expected of different preservatives than did the tests made by Mr. Bond (of the United States Forest Service), reported at the meeting of the American Wood Preservers' Association last year. The test herein described made use of the usual type of wood used in treatment. The ties taken were the kind of ties which were being put through the cylinder every day. The moisture factor was practically the same in the comparative pieces taken from the same tie. Furthermore, a commercial comparison should be made between the creosote-coal-tar combination and some other straight creosote oil. The comparison shown by the various tests made by Mr. Bond are largely on the basis of different types of coal-tars. From a large number of additional tests made by the writers, one is chosen for further illustration.

A stick of sap pine was kiln dried for a year and sawed into blocks. Only one hole was bored, in this case, into each piece, and three different preservatives were tested, namely, a standard English creosote fulfilling the American Railway Engineering Association specification No. 1, a light American creosote, and a combination of 80 per cent. of the American creosote and 20 per cent. coal-tar. Fifteen c.c. of each preservative were used. The pieces of wood were kept in a drying oven at 180 degrees Fahrenheit for six hours before the actual test, and again after the liquids were poured into the holes. The resulting penetration is shown on plate No. 3.

The analyses of the three preservatives used were as follows:

	English Creosote.	Light American Creosote.	80 per cent. American Creosote, 20 per cent. Coal-Tar.
Number	2314	1976	
Sp. Gr. at 100° F.	1.044	1.006	1.031
	Per cent.	Per cent.	Per cent.
210° C.	3.6	15.70	11.42
235	26.6	33.74	28.17
270	22.7	26.27	23.90
315	16.8	12.91	11.30
355	20.3	10.50	9.27
Residue	8.9	10.50	15.25

The penetration in this instance was every bit as good for the coal-tar-creosote combination as it was for the American Railway Engineering Association No. 1 oil.

Taking all of these tests into consideration, the conclusion has been reached that for practical purposes the penetration obtainable with this type of mixture (that is, by mixing a percentage not to exceed 20 per cent. low-carbon coal-tar with creosote oil) is as good as that which can be obtained by using the creosote alone.

In actual practice the extent of penetration with creosote oil is usually determined by sawing a number of different ties or pieces of lumber, and noting the actual penetration obtained. This is, to be sure, a very rough method and usually requires sawing a considerable number of different pieces. The variation in absorption and penetration for different pieces of wood is very great, even when the greatest care is taken to have the same species represented in any one treatment. Our decisions are frequently determined, however, by just such so-called practical tests. We go through the treating plant and saw six or eight ties, and if we find that a fair percentage shows an acceptable penetration, we consider that the treatment is a good one. If, on the other hand, we find that a large number show a poor penetration, we consider the treatment as poor. The sawing of such ties is, unfortunately, the only method, aside from making actual borings, which we have for gaging penetration. Such sawing tests must always be accepted with a good deal of reserve, because they may give rise to wholly incorrect conclusions. It is of the utmost importance that in any discussion on penetration the fact be kept in mind that no two pieces of wood will react exactly alike in the creosoting cylinder, and that judgment based on sections made from ties picked from one or two runs are apt to be very misleading. With a full appreciation of this fact, but with the idea of seeing to what extent ties as nearly alike as possible absorb creosote when compared with creosote to which low carbon coal-tar had been added, a series of tests was made with red oak.

A whole cylinder charge of dry red oak ties was treated with creosote oil. Another cylinder charge of the same kind of red oak ties was treated with this same creosote, to which 20 per cent. coal-tar had been added. A considerable number of ties in each charge were weighed individually before and after treatment. These individually-weighed ties were laid aside after treatment and were exposed to the air for some two months. A number of ties from each series were then selected. The selections were made from the table of weights and absorptions in such manner that two ties were selected, one from the creosote series and one from the creosote-coal-tar series, having approximately the same weight before treatment and approximately the same absorption of creosote and creosote-coal-tar, respectively. These ties were then cut on a very cold day, the sections being made under the rail base. Photographs were taken immediately after the sections were made. A number of these are reproduced on plates 4, 5 and 6. So, for instance, in one case a tie

weighed 121½ lbs. before treatment and absorbed 20 lbs. of creosote oil; from the second series a tie was selected which weighed 124½ lbs. before treatment and absorbed 21 lbs. of creosote-coal-tar mixture. In another case, both ties weighed 126 lbs. before treatment, the one absorbing 11 lbs. of creosote and the other 14 lbs. of creosote-coal-tar mixture. A critical examination of all of these ties so sectioned failed to show any material difference in the extent of penetration. In fact, it was almost impossible to tell one from the other, except that the ties treated with the creosote-coal-tar mixture were blacker, due to the presence of free carbon. A glance at the photographs will show how difficult it is to establish any definite basis according to which penetration can be gaged.

There is no such thing as saying that one tie is better than another in terms of depth of penetration, because in ties like red oak the oil is in streaks or spots throughout the tie. No two people will ever agree which of the two ties, which weighed respectively 113 and 117 lbs. before treatment (see plate 6), shows the better penetration. It had been suggested that we employ half ties and treat one with creosote and the other with creosote-coal-tar mixture. This was tried, but it was found that in such short pieces the actual amount absorbed was so large that a definite comparison could not be obtained. It is fully realized that the illustration presented should be taken only as such tests are considered at the treating plants. They are presented, however, because engineers frequently base their opinion concerning this subject of penetration on sections made of actual ties.

One should not lose sight of the fact that it may take a slightly longer period of pressure to obtain the extent of penetration with the mixture that one can obtain with straight creosote, but practical experience at those plants where the combination of coal-tar and creosote oil has been used for several years, bears out the conclusion just made, that equally as good penetration can be obtained with the mixture as can be obtained with the creosote.

The only property of the coal-tar and creosote combination which might retard the penetration is the presence of a small amount of free carbon in the mixture. This free carbon filters out on the ends of the wood and it may to a certain extent retard the penetration of the oil. This retardent action is more apparent than real. Until recently it was supposed that none of the free carbon particles could penetrate the wood. Everyone has been struck with the fact that the wood treated with the coal-tar-creosote mixture, when cut into, is blacker than wood treated with creosote without the coal-tar addition. Not until recently, however, was it proven that carbon particles can actually enter into wood fiber with the oil.

Bailey (Forestry Quarterly, Vol. II, page 11, 1913), in a series of experiments, used an aqueous mass containing very finely divided particles of carbon held in suspension as a test liquid, to determine the manner of penetration of liquids into wood fiber. He states: "Obviously this dark-colored liquid could penetrate only when actual openings existed in

the cell walls." He shows a number of photographs in which the carbon particles are plainly visible in the cells. The presence of small portions of free carbon in the creosote, therefore, need not necessarily be regarded as materially retarding the entrance of the oil, even from a theoretical standpoint, because some of the free carbon enters with the creosote oil.

The conclusions to be drawn, therefore, both from actual experience with pieces of wood as well as from theoretical consideration, are that the penetration which can be secured with the creosote to which approximately 20 per cent. of low carbon coal-tar has been added, will not in any way be inferior to that which could have been obtained had the same pieces of wood been treated with creosote alone. Any slight retardation, to whatever cause it may be due, can easily be made up by a slight increase in the time of pressure.

RELATION OF COST.

In the President's address of the American Wood Preservers' Association in 1913, E. A. Sterling stated: "The procuring of an adequate supply of creosote at a reasonable cost may safely be considered as a vital factor in the wood preserving industry of the United States, even though other preservatives, including zinc chloride, are used in large quantities." The consumption of creosote in the United States in 1912 amounted approximately to 83,000,000 gallons, of which about three-fourths was imported. This means that about 20,000,000 gallons were manufactured in the United States. Owing to the character of the crude tar from which the creosote oil is distilled and to varying market conditions, a considerable percentage of the oil furnished for consumption will not meet the standard specification No. 1 of the American Railway Engineering Association. These oils, however, are sold at a lower price than many of the imported oils which fulfill the specification No. 1 of the American Railway Engineering Association. The average consumer is consequently confronted with the alternative of buying an oil meeting the specification No. 1 and paying higher prices for the same or of buying an oil below this specification at a cheaper price. Given the alternative of buying the American Railway Engineering Association oil No. 1 or an oil which will not conform to this specification, there can be no question but that it is better policy to buy the highest grade oil, even at a higher price. The condition of the oil supply is such, however, that the amount of No. 1 oil is limited, and many consumers are forced either to buy the lower grade oil or to have none at all. Under these circumstances the question is: Shall the low-grade oil be used and how? Two alternatives suggest themselves to the writers in this connection. One is to use the low-grade oil in larger quantities, or to use the low-grade oil and add a certain percentage of coal-tar, which can be purchased at about the same price as the low-grade oil.

Where the oil is only slightly inferior to the American Railway Engineering Association specification No. 1, it will probably prove best to use larger quantities of such oil; where it is equal to the American Railway Engineering Association No. 3 oil, it is believed that the addition

of coal-tar will be good policy, remembering the various considerations presented above. One will thereby obtain an oil, at a lower cost, which will have many of the qualities of the high-grade oil and which, to a certain extent, will do away with the necessity of using increased quantities.

Another point which should be considered in this connection is that we have after all practically no information as to the actual number of years which a given quantity of creosote oil of any grade will preserve any given piece of wood. Some railroads use about two gallons of creosote, or less, per tie, whereas others use about two and one-half gallons for the same sized ties. If two gallons is considered a good risk, the addition of a half gallon of coal-tar to two gallons of creosote oil is certainly as good a risk. In fact, with the retentive influence of the coal-tar, the probability is that the two original gallons of creosote oil to which coal-tar had been added will stay in the wood longer than the two gallons to which no coal-tar had been added. Whichever way one looks at it, therefore, the risk of adding coal-tar to creosote appears to be a fair one, and in many instances it may be better policy to use the combined oils rather than to use larger quantities of the poorer oil, particularly in connection with the economical creosoting processes so largely employed at the present time.

Reference has been made to the fact that larger quantities of No. 2 or No. 3 oil always mean an increased cost. It has also been pointed out that there is at present no very good basis from which one could judge what increased quantities are desirable, and consequently how much the increased cost would be. In view of the fact that the basis of comparison of various oils is largely derived from the degree of permanence which such oils are supposed to have after once injected into timber, it is suggested that the permanence of the oil might be used as a basis for estimating the relative quantities of different oils to be used for similar purposes. It is fully realized that such estimates must be regraded from a purely theoretical standpoint. We have not yet sufficient data to make such estimates more than theoretical. In order to illustrate the possibility in a graphical way, we have taken the figures obtained from the evaporation of various oils from pine and maple blocks referred to above (see charts 4 and 5).

Referring to chart No. 5 (oil evaporation from pine blocks), and taking the highest percentage of evaporation for oil No. 6 (A. R. E. A. No. 1 oil), oil No. 1 (A. R. E. A. No. 3 oil), and oil No. 5 (A. R. E. A. No. 3 oil plus 20 per cent. coal-tar), and using A. R. E. A. No. 1 oil as a standard, we find that the evaporative ratio of these oils are as follows:

A. R. E. A. No. 1 creosote	1.00
A. R. E. A. No. 3 creosote	1.68
A. R. E. A. No. 3 creosote plus 20 per cent. coal-tar	1.29

Taking A. R. E. A. No. 1 oil as a standard for the quantity to be used per tie, and assuming that the amount to be used is two and one-

half gallons per tie, we find the ratio of quantity, based on the evaporative ratio as follows:

No. 1 oil..............................2.50 gal. per tie
No. 3 oil..............................4.20 gal. per tie
No. 3 oil plus 20 per cent. coal-tar........3.22 gal. per tie

Assuming the price to be 7 cents per gallon for all of the oils, we get a total cost, based on this evaporative ratio, as follows:

A. R. E. A. No. 1 creosote.................. 17.5 cents
A. R. E. A. No. 3 creosote.................. 29.4 cents
A. R. E. A. No. 3 creosote plus 20 per cent. coal-tar .... 22.5 cents

If, as appears fair, we charge a slightly higher price for A. R. E. A. No. 1 oil, that is, 9 cents instead of 7 cents, we get the total cost for treatment on this basis, as follows:

A. R. E. A. No. 1 creosote.................. 22.5 cents
A. R. E. A. No. 3 creosote.................. 29.4 cents
A. R. E. A. No. 3 creosote plus 20 per cent. coal-tar .... 22.5 cents

Using the same method on the basis of the results for maple blocks (chart No. 4), the final price obtained for A. R. E. A. No. 1 oil is 22.5 cents; for No. 3 oil, 25.3 cents; and for No. 3 oil plus 20 per cent. coal-tar, 19.7 cents.

For convenience these figures are presented in tabulated form herewith:

	Evap. Ratio.	Quantity.	Price.	Total Cost.	Price.	Total Cost.
Pine.						
A. R. E. A. No. 1 creosote.....	1.00	2.50 gal.	7c	17.5c	9c	22.5c
A. R. E. A. No. 3 creosote.....	1.68	4.20 gal.	7c	29.4c	7c	29.4c
A. R. E. A. No. 3 creosote plus 20 per cent. coal-tar........	1.29	3.22 gal.	7c	22.5c	7c	22.5c
Maple.						
A. R. E. A. No. 1 creosote.....	1.00	2.50 gal.	7c	17.5c	9c	22.5c
A. R. E. A. No. 3 creosote.....	1.45	3.62 gal.	7c	25.3c	7c	25.3c
A. R. E. A. No. 3 creosote plus 20 per cent. coal-tar........	1.12	2.81 gal.	7c	19.7c	7c	19.7c

A study of these figures will show that if it be true that A. R. E. A. No. 1 oil is the best oil, and consequently that Nos. 2 and 3 should be used in larger quantities, because they disappear more rapidly from the wood than does No. 1 oil, it will certainly be true that larger quantities of Nos. 2 and 3 oils will cost more than a treatment with No. 1 oil; that is, it will always be the best policy to use No. 1 oil wherever one can.

The second conclusion from this study is that it will be cheaper to use No. 3 oil with the slight coal-tar addition than to use correspondingly larger quantities of the No. 2 or 3 oil without the coal-tar addition.

We wish to point out again that the figures in this table should be taken only as an individual study and from one set of experiments, and they are simply presented for the purpose of indicating a possible basis for discussing how we should arrive at cost estimates where different qualities of oil are used. It would be interesting to have these evapor-

ative experiments made on a larger scale for different quantities of oil, and we are at the present time engaged in carrying out such a series.

While these cost considerations are of great importance, nothing herein is to be taken as implying that the decision as to whether coal-tar should be added to Nos. 2 or 3 A. R. E. A. oil, should be based entirely on cost considerations. This phase of the matter will enter into the discussion only in such cases where a coal-tar addition is considered advisable, because of the difficulty or impossibility of getting No. 1 oil. There are many railroads in this country who can get No. 2 or 3 oil, not only at lower prices, but who can get such oils where they cannot get No. 1 oil, except at very advanced prices or not at all. In other words, the amount and quality of the creosote available at any one particular point will be the first point to be considered, and where it is found that an adequate supply of Nos. 2 or 3 oil is available, then it will be time to consider the possibility of adding the coal-tar, both from the standpoint of getting the proper quantity of oil and at a lower cost than would have to be paid for the No. 1 oil.

SUMMARY.

Summarizing the factors presented, we find:

I. Amount Used.

Since 1908 approximately 24,500,000 ties have been treated with a combination of 80 per cent. creosote oil and 20 per cent. refined coal-tar. Practically all paving blocks since 1907 have been treated with such a combination. The total amount of creosote oil used in the United States in 1912 was 83,666,490 gallons. During 1912 it is estimated that 12,500,000 gallons of coal-tar-creosote combination were used for the treatment of ties, and about 14,000,000 gallons for paving blocks, or a total of 28,000,000 for both, or about 31 per cent. of all the oil used. Adding to this similar oil used at plants from which no figures are available, a conservative estimate indicates that about 40 per cent. of all the creosote oil used in 1912 was a coal-tar-creosote combination.

II. What Coal-Tar Is.

Coal-tar is one of the products obtained from the destructive distillation of coal-tar, either at retort gas works or at by-product coke-oven plants, and the tar so obtained is gas-house tar or coke-oven tar. Gas-house tar usually has a high percentage of free carbon, coke-oven tar a low percentage of free carbon. Both tars when redistilled yield creosote oil, that is, the coal-tar is the mother liquor from which creosote oil is obtained. Only a low-carbon tar should be used for addition to creosote oil.

III. Previous Uses of Coal-Tar.

Coal-tar was added to creosote oil in large quantities in the early days of creosoting, and is still added to creosote oil in England to give a black color to creosoted wood.

IV. What Happens When Coal-Tar Is Added to Creosote Oil.

When coal-tar is added to creosote oil, the two substances, being composed of the same chemical compounds, unite. The combination is in the nature of a "solution," and it is not merely a physical "mixture." When thoroughly mixed, they do not separate. The addition of coal-tar to creosote oil cannot be called an "adulteration."

The addition of a small amount of coal-tar to creosote oil reduces the amount of evaporation which takes place. The combination remains in wood longer than the same creosote oil without the coal-tar addition.

V. Relative to Antiseptic Properties.

The experience of many years has shown that the high-boiling constituents of creosote oil are the most effective in preserving wood. Coal-tar is largely composed of high-boiling compounds. The presumption therefore is that by adding a small amount of coal-tar to creosote oil the antiseptic value of the mixture is not reduced, but may be enhanced.

VI. Relation to Penetration.

Tests at treating plants and under exact conditions show that the penetration obtained with a combination of 80 per cent. creosote oil and 20 per cent. refined coal-tar is as good as that obtained with good creosote oil. In any event, a slight increase in the time of pressure will give as high a penetration as can be obtained with the lighter creosote oils.

VII. Relation to Supply and Cost.

Only a limited supply of high-grade creosote oil is available, whereas large quantities of lower-grade creosote oils are on the market. With the economical creosoting processes now used, injecting small quantities of oil into timbers, it is desirable to retain as much oil in the wood as possible. Low-grade oils lose a large percentage in a very few years. Anything which will retard this loss will make it possible to use these lower-grade oils to good advantage. One of the principal reasons for adding coal-tar to these lower-grade oils is to make them better adapted to the economical creosoting processes, and at no increase in cost.

VIII. Conclusions.

The chief object of this discussion has been to present results of certain experiments made during recent years with creosote oil to which low carbon coal-tar had been added. The writers firmly believe that the best results with creosoting will always be obtained by the use of oil equivalent to the American Railway Engineering Association No. 1 oil. They wish to point out distinctly that, in their opinion, the refined coal-tar should never be added to American Railway Engineering Association No. 1 oil. The information available seems to indicate that the addition of low-carbon coal-tar to oils inferior to American Railway Engineering Association No. 1 specification oil does not reduce the penetration obtainable, provided suitable methods are adopted at the creosoting plants to bring about the proper mixture and injection. They find also that

little risk is taken from the antiseptic standpoint. The results also seem to indicate that the addition of the refined coal-tar materially tends to retain creosote oil in the timber. The addition also makes possible the utilization of the poorer grades of creosote oil, which are coming more and more into use, and that where such oils are used with the coal-tar addition, smaller quantities can be used at a probably lower cost than where larger quantities of the same inferior oils are used. Remembering these indications, it is pointed out that the coal-tar addition, when properly used, is worthy of trial. Where it is thought desirable to add refined coal-tar to creosote oil, it should be observed that only a low-carbon coal-tar should be used, that is, one having a percentage not to exceed 5 or 6 per cent. of free carbon.

Before the combination of creosote and coal-tar is used for the impregnation of timber, the two substances should be thoroughly mixed in a tank reserved for that purpose, preferably at a temperature of 180 degrees Fahrenheit, and during the process of impregnation the temperature of the mixture in the cylinder should be maintained at least at 180 degrees Fahrenheit.

One of the most important considerations is that if the coal-tar is used anywhere, it should be mixed with the creosote oil under the immediate direction of the railroad company, and with their full knowledge. The practice which has come about in various quarters of selling creosote oil mixed with coal-tar as a No. 1 specification oil, should be stopped; and the caution is added that the greatest care should be taken, where timber is treated with creosote, where a No. 1 specification is called for, that the specification for such oil as printed in the Manual, be rigidly enforced.

REPORT OF SPECIAL COMMITTEE ON GRADING OF LUMBER.

DR. H. VON SCHRENK, *Chairman;*
W. McC. BOND,
D. FAIRCHILD,
R. KOEHLER,
A. J. NEAFIE,

B. A. WOOD, *Vice-Chairman,*
W. H. NORRIS,
R. C. SATTLEY,
J. J. TAYLOR,

Committee.

To the Members of the American Railway Engineering Association:

The Special Committee on Rules for the Grading and Inspection of Maintenance of Way Lumber has, during the past year, been engaged in trying to formulate additional grading rules for such classes of lumber as have not yet been standardized. The work has unfortunately been retarded, owing to the fact that many of the rules for such timbers, particularly hemlock and western timbers, are still in a process of development. It was therefore not thought advisable to force the formulation of such rules by the Committee, but to await their definite adoption by the associations manufacturing such classes of lumber. It is anticipated that the rules for hemlock and some of the Pacific Coast timbers will be in shape for presentation at the next convention.

The Committee reports progress in the adoption of the rules already in the Manual. A recent communication is received from one of the largest associations manufacturing lumber, advising that the changes made in the rules as adopted by this Association last year are very slight. Your Committee would respectfully urge all members to use these rules in the purchase of Maintenance of Way lumber. They may not always fit the requirements, nor will they always quite agree with the commercial grades of manufactured lumber, because the latter changes from year to year. The changes, however, do not materially affect the quality as described in the grades. A more universal use of the lumber grades as already adopted in the Manual will tend towards the elimination of odd sizes and grades.

Respectfully submitted,

SPECIAL COMMITTEE ON GRADING OF LUMBER.

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

A. F. Dorley, *Chairman;*
J. L. Campbell, *Vice-Chairman;*
C. C. Cook,
A. Mordecai,
R. H. Gaines,
W. A. Parker,
W. S. Lacher,
W. L. Rohbock,
E. G. Lane,
Chas. E. Thomas,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee submits herewith a report of its proceedings and work accomplished during the past year. To facilitate the handling of the work assigned to it by the Board of Direction, it was decided to divide the Committee into three Sub-Committees for detailed study of the three subjects assigned, as follows:

Sub-Committee No 1—"Report on the Design and Relative Economy of Track Pans from an Operating Standpoint;" E. G. Lane, Chairman.

Sub-Committee No. 2—"Report on Water Treatment and Result of Study Being Made of Water Softeners from an Operating Standpoint;" W. S. Lacher, Chairman; W. A. Parker, A. F. Dorley, R. H. Gaines.

Sub-Committee No. 3—"Report on Recent Developments in Pumping Machinery;" C. C. Cook, Chairman; A. Mordecai, W. L. Rohbock, J. L. Campbell.

In addition to the various meetings of Sub-Committees, meetings of the Committee were held in Chicago on May 26 and September 15, and in Pittsburgh on October 27.

(1) DESIGN AND RELATIVE ECONOMY OF TRACK PANS FROM AN OPERATING STANDPOINT.

The Committee desires to report progress only at this meeting. The subject has had considerable study and investigation, but the information is not in form for final submission at this time.

(2) WATER TREATMENT AND RESULT OF STUDY BEING MADE OF WATER SOFTENERS FROM AN OPERATING STANDPOINT.

The report on this subject has been divided into three sub-headings:

(1) Economy of water treatment.

(2) Present situation as to water treatment on railroads.

(3) General rules for the installation and operation of water softeners, and the use of treated water, based on a study of water softeners from an operating standpoint.

(1) ECONOMY OF WATER SOFTENERS.

Much information has been published from time to time, showing clearly the benefits to be derived from the treatment of water for hardness, but on the whole this has been of a descriptive character, containing insufficient numerical data to show, mathematically, the relation between the character of the water and the economy of treatment. The section of the Manual devoted to Water Service contains a formula for determining the justifiability of treatment, which is in fact a mathematical expression of the principles of water treatment. The difficulty, however, is in assigning numerical values to the various terms. The principal reasons for this are as follows:

(1) Many of the benefits are of such an intangible nature as to be very difficult of mathematical expression.

(2) The necessary subdivision of cost of locomotive, operation and maintenance is not generally obtained.

(3) Presence of other variables, as in making a comparison between two divisions of a road, one with softeners and one without, or on a given division, before and after installation of softeners. In the one case, we encounter variation in physical conditions, traffic, personnel, in the other changes in equipment and policy, while both are affected by transfer of power from division to division.

Efforts on the part of your Committee to collect data giving numerical values for the economy or benefits of water treatment have, therefore, not been met with an appreciable success. In Appendix A your Committee submits an effort at an analytical solution of the problem.

Appendix B gives results of water treatment on two roads in the middle West. In one case the economy of treatment on the entire system is shown, and in the other a comparison is made between three divisions of a road as to boiler repairs, two divisions with water softeners and one without.

(2) CURRENT PRACTICE AS TO WATER TREATMENT.

The present situation as to the treatment of water on railroads presents a rather complex outlook. While softening plants are in use on nearly all roads, and some lines have installed a sufficient number to eliminate bad water at practically all important water stations, it is a fact that a large number of roads are resorting to other means, in efforts to eliminate the effects of bad water. These are enumerated as follows:

(1) The use of soda ash (sodium carbonate) directly in locomotive tanks.

(2) The use of some proprietory anti-scaling compound, with or without an anti-foaming ingredient, either in the locomotive tank, or directly in the boiler.

(3) The treatment of water with soda ash only, in the road tanks, generally with provision, through a float outlet and a sludge valve, for the removal of a portion of the sludge. These "soda ash plants" permit

of an accuracy of proportioning impossible with Methods No. 1 or No. 2. They are used in some instances as auxiliaries to complete softening plants, to give a partial treatment to water at the less important stations where the installation of a softening plant was not considered justifiable.

The table below gives the practice as to water treatment on six representative trunk lines in the middle West.

TABLE SHOWING CURRENT PRACTICE AS TO TREATMENT OF WATER ON SIX TRUNK LINES IN THE MIDDLE WEST

Line	No. of Treating Plants Installed		No. of Treating Plants in Operation		Use of Soda Ash as a Boiler Compound (in Engine Tanks)	Use of Anti-Scale Boiler Compounds other than Soda Ash
	Complete Treatment	Soda Ash Treatment	Complete Treatment	Soda Ash Treatment		
A	45	0	45	0	Is not used.	For experimental purposes in a few localities
B	42	0	42	0	On divisions where plants have not been installed.	None used.
C	6	0	5	0	Very extensively.	In a few localities.
D	115	0	112*	0	On branch lines and at points where no softeners have been installed on main lines.	None used.
E	9	86	†5	86	At 6 stations.	For experimental purposes on a single division.
F	28	25	28	25	Is not used.	Silicate of Soda used in moderately hard water territory.

* Three abandoned on account of station closed.
† Three are lime soda ash plants, two are barium hydrate plants

The failure of the roads to go more generally into the use of complete water softeners is accounted for by the fact that installation of water softeners involves a considerable initial outlay as compared to the use of compounds, which require no plant at all.

It is also due to the fact that on one or two roads, due to good organization and intelligent supervision, excellent success has been attained with the use of soda ash plants, which involve little investment for plants as compared to complete treatment plants.

Investigation of the failure or abandonment of such softening plants, as have been brought to the notice of the committee have been found to be the result of faulty design, supervision or operation, rather than any inherent fault in the principle of water softening. The general rules for installation and operation given hereafter are in part the result of such investigation.

(3) GENERAL RULES FOR INSTALLATION AND OPERATION OF WATER SOFTENERS AND USE OF TREATED WATER BASED ON STUDY OF WATER SOFTENERS FROM AN OPERATING STANDPOINT.

(A) Design and Installation.

(1) The plant must be of adequate capacity. It is necessary to anticipate possible increases in the consumption of water at the station considered. This may result from increase in volume of traffic, reduction in number of stops for water, due to increase in size of engine tanks, or preference for treated water over that at adjoining stations not treated. The prospective plant must be carefully investigated to ascertain if the proportions of all parts are such as to insure the rated capacity. It is not safe to accept a plant requiring a reduction in the time for treatment because of special appliances purported to accelerate the process.

(2) The installation of softening plants must follow a systematic plan. Greater success is generally obtained by completing the installation on one division first, rather than installing plants at individual points of especially bad water. A softening plant is not completely successful as long as engines served have badly encrusted boilers, and desired improvements in this respect cannot be fully obtained when engines take from other stations, water which is high in incrusting matter. This condition, of course, would not obtain in the case of a plant at the single intermediate water station for passenger engines, where the water at the terminals was of good quality, or in a plant at a terminal serving a great many switching or transfer engines that receive water from no other source.

(3) The mechanical features of treating plant must be so simple as not to require expert attendance. Where proportioning is automatic, it is essential that the machine is not easily thrown out of adjustment.

(4) Feasibility of treatment of a given water should be carefully investigated. This applies especially to waters containing large proportions of incrusting sulphates or sulphates in combination with quantities of alkali salts. Treatment of such water by the Porter-Clark process may result in water containing such high proportions of foaming solids as to be entirely unusable.

(B) Operation, Maintenance and Supervision.

(1) Adequate supervision is necessary to successful operation of a softening plant. Such supervision must be exercised at least in part by a chemist, or an engineer having adequate knowledge of water treatment. A tendency on the part of operating and mechanical officials to underestimate the importance of treating plants has frequently been evidenced, emphasizing the necessity for supervision on the part of some one who has the interests of the plant at heart.

(2) Provision should be made for frequent analysis of both the treated and raw water. This is necessary, principally as a check on the treatment, and also to some extent on account of changes in the condition of the raw water. This is of more importance with water from

streams or surface reservoirs; but even with wells, changes occur occasionally, due to entrance of surface water, or perhaps to failure of supply from one of the several water-bearing strata.

In order that the analyses shall be effective, they must be made under the supervision of a competent chemist. Simple tests with soap and acid solutions which are of sufficient accuracy to handle ordinary operating results, should be made at least once a week by the chemist for check purposes.

Where creek or other water subject to sudden changes is softened, a simple testing outfit, accompanied by specific instructions and chart for each individual water, should be provided for the plant operator, who with little practice and weekly check by the chemist will become sufficiently proficient to make formula changes to meet the variations in character of water.

(3) Proper mechanical operation and maintenance of the treating plants must be provided for through adequate supervision on the part of a supervisor of water service, bridges and buildings, or equivalent officer. Where the division organization is in use, a check on such supervision must be maintained by an engineer directly responsible for the water treatment.

(4) Where the plant is inadequate in size, arrangements should be made to use raw water to such an amount as to permit of proper treatment of all water that passes through the softener.

USE OF TREATED WATER.

One of the objections against water softeners is the foaming of boiler water following treatment. There is good reason to believe that the importance of this objection is occasionally overestimated. This is evidenced by the fact that natural alkali waters are being used successfully on some Western roads, which contain many times the amount of foaming solids which have caused criticism of treated waters. Foaming is of much more immediate concern to the enginemen than the presence of scale in the boiler. It serves as a good excuse for delays.

Foaming from treated water is due to the presence of sodium salts as a result of treatment for incrusting sulphates, together with such quantities of the alkali salts which may have been present in the raw water. The condition is aggravated and to a large extent due to the presence of suspended matter in the water. For this reason foaming is more prevalent immediately after the introduction of treatment, due to the loosening of old scale in the boilers. Difficulty from this source will also occur where engines receive at other stations water which is high in incrusting solids. Any excess of soda ash in the treated water will re-act on the untreated water causing a precipitate which is carried into the boiler.

Since foaming takes place with the concentration of the foaming solids and the accumulation of suspended matter, one remedy for foaming is to prevent the condition of concentration by blowing down the boilers or periodic washing and changing the boiler water. A method for determining the amount of blowing off necessary to keep the concentra-

tion within definite limits is given fully in the report of the Water Service Committee in Vol. 8. Owing to the accumulation of suspended matter in the water legs of the firebox, blowoff cocks, as ordinarily located, will remove a large part of these deposits. In fact, it is argued by the advocates of systems of treatment which do not permit of complete removal of the suspended matter before discharged into the engine tanks, that sufficient blowing down to keep the water within reasonable limits of concentration of foaming solids will also be sufficient to remove all accumulations of suspended matter.

There is a wide variation in the practice as to blowing off on various railroads. Some roads depend entirely on the blowing down, washing and changing of water at terminals. Other roads, by requiring enginemen to blow off engines systematically on the road, are keeping the degree of concentration of dissolved solids and the quantities of suspended matter within the desired limit, and are at the same time greatly increasing the allowable interval between boiler washings.

The advantages of frequent short interval road blowing off are as follows:

(1) Less chance for mud burning.

(2) Less chance for injury to sheets, since amount of water removed at one time is relatively small, and there is less opportunity for material change in temperatures.

(3) Amount and frequency of blowing off is modified to meet the varying conditions and the degree of concentration may be kept at a reasonably uniform standard.

Objections to road blowing off are as follows:

(1) Danger of failure of blowoff cock to close with resultant engine failure.

(2) Possible danger to persons on the right-of-way, and spattering of structures and equipment, especially passenger trains.

(3) Objection to noise, particularly in cities.

In addition to the above objections, following are some obstacles which tend to make effective blowing off difficult:

(1) Difficulty enforcing regulations as to blowing off.

(2) On long hills, where foaming is most likely to occur, the water consumption, due to the severe working of the engine, taxes the injectors to such an extent that further reduction of water in boiler by blowing off is not permissible.

Anti-foaming compounds are, of course, in general use to overcome this condition, but experiments go to show that with a minimum of suspended matter the content of alkali salts can be carried to a considerable degree of concentration without trouble from foaming. The primary measure, therefore, should be to obtain clean boilers and clean water so far as practicable.

There are, of course, conditions where concentration of foaming solids is so great that the required amount of blowing off would be both impracticable and uneconomical, and it is necessary to resort to anti-foaming compounds.

EXAMPLE ILLUSTRATING A METHOD FOR CALCULATION OF THE ECONOMIES RESULTING FROM THE INSTALLATION OF WATER SOFTENERS.

In estimating the beneficial effects of water softening, the following were considered:

(a) Loss of fuel due to the insulating effect of scale on flues and other heating surfaces.
(b) Renewal of flues account of scale accumulation and injury to flue ends from repeated caulking.
(c) Caulking of flues and other enginehouse boiler repairs.
(d) Loss of engine time during periods of boiler and firebox repairs.

No consideration was given to the indeterminate transportation losses and interruptions to traffic due to engine failures resulting from leaky flues; nor the saving in engine time and enginehouse labor for washing out boilers brought about by removal of the suspended matter in natural waters by treatment.

The percentages of fuel loss used below were determined by a series of tests made at the University of Illinois. The thicknss of scale with the water of 20 grains average hardness was taken at 1/4-inch at time of flue renewal, and 1/16-inch with the water of 7 grains average hardness. The price of coal was taken at $1.45 per ton, with 12 cents additional for handling, and 36 cents for hauling, or a total of $1.93 per ton on the tender.

The life of flues, cost of boiler repairs and loss of engine time used in the estimate are the average figures obtained from the existing conditions on various railroads in the middle West.

The cost of $234.00 for removal of flues represents the average of $125.00 for labor for each removal for cleaning, and cost of 13½ cents per foot of flues, less scrap value for each sixth removal.

The $13.00 value per engine day represents 10 per cent. for depreciation and interest on a valuation of $16,000.00 per engine, and 7 cents per engine mile to cover maintenance.

Following are comparative estimated operating figures of a 106-ton engine, with a mileage of 45,000 miles per year, a coal consumption of 4,500 tons and water consumption of 7,500,000 gallons:

20-Grain Water.		7-Grain Water.	
15.6 per cent. loss of fuel due to 1/8-inch average scale..	$1,354	7.82 per cent. loss of fuel due to 1/32-inch average scale	$ 677
1 1/3 set of flues at $234......	312	4/5 set of flues at $234......	187
Roundhouse flue repairs.....	252	Roundhouse flue repairs.....	142
13 days' loss of engine time at $13	169	8 days' loss of engine time at $13	104
	$2,087		$1,110

Saving per locomotive per year, $977.00.

As the difference of 13 grains of hardness in 7,500,000 gallons of water represents 13,929 lbs. of incrusting solids, it is concluded that the saving of $977 per locomotive represents 7 cents per pound of excess scaling matter entering the boiler, or 13 cents per 1,000 gallons of water treated.

To obtain the net saving we must subtract from the above the cost of treatment, and the cost of water wasted in blowing off to overcome foaming.

Cost of treatment should be made up of the following:

(a) Interest and depreciation of the plant.
(b) Cost of chemicals.
(c) Cost of operation, maintenance and superintendence.

The loss due to blowing off has been thoroughly discussed previously in the report of the Committee in 1907.

In making a comparison between the results above given and those in the first report shown below, it is to be noted that the former is based on the removal of 13 grains of incrustants per gallon, or 1.85 lbs. per 1,000 gallons, while the latter is based on the actual removal of an average of 23 grains per gallon, or 3.3 lbs. per 1,000 gallons.

A REPORT SHOWING THE ECONOMIES RESULTING FROM THE INSTALLATION OF WATER SOFTENERS ON A LARGE RAILROAD IN THE MIDDLE WEST.

The installation of water softening plants on this system began in 1905, and to date a total of 45 plants have been provided and are in operation. The total investment is approximately $136,000.

The average amount of water treated for locomotive and stationary boiler purposes per year, by reducing the hardness to a point at which it will form practically no scale, is 1,692 million gallons.

The total average amount of scale-forming solids removed from the water by treatment per year is 5,537,000 lbs., or an average of 3.3 lbs. per 1,000 gallons.

In calculating the benefits of water softening in the figures given below, the following losses resulting from the use of bad boiler waters were considered:

(a) Frequent renewal of flues and other parts of boilers account of scale accumulation; also injury to flue ends from repeated caulking.
(b) Labor caulking flues and other enginehouse boiler repairs.
(c) Loss of engine time during periods of boiler and firebox repairs.
(d) Loss of fuel due to the insulating effect of scale on flues and other heating surfaces.

The total loss per year that would result from the above causes in the absence of water treatment on this system is calculated from the best conservative figures available from the experience on this and other roads to be about $166,771, or 9.8 cents per 1,000 gallons treated, or 3 cents per pound of incrusting solids removed.

A COMPARISON AS TO BOILER REPAIRS ON DIVISIONS OF A WESTERN RAILROAD, SHOWING EFFECT OF WATER TREATMENT

Divisions A and B are Equipped for Water Treatment, Division C was without Treatment. The cost of Machinery Repairs is not included in the Statement. The Loss of Time includes that due only to Work on the Boilers.

	Div. A	Div. B	Div. C	Loss Div. C, Compared with Div. A	Loss Div. C, Compared with Div. B
RUNNING REPAIR DATA BOILER WORK, ALL ENGINES.					
Average Engines in Service per month...	112	80	61		
Cost Boiler Work—Running Repairs.. ..	$15328.50	$19162.36	$25066.25		
Average per month....................	1277.38	1596.96	2088.85		
Cost per Engine in Service per month...	11.40	19.96	34.24		
Cost based on No. Engines on Div. C...	695.40	1217.56	2088.85	$1393.45	$871.29
CLASSIFIED REPAIR DATA BOILER WORK. (New 800 and 900 Passgr. and 1900 and 2000 cls. Frt. on Div. A. & Div. C. and 800 and 1700 on Div. B.)					
Number Engines in Comparison.........	30	13	39		
Total Cost Boiler Work (Period Averaging 16 months)....................	$9350.02	$3638.49	$26952.92		
Cost per Engine per Month Service......	19.48	17.49	43.19		
Cost Based on No. Engines on Div. C..	1188.28	1066.89	2634.59	$1446.31	$1567.70
LOSS OF SERVICE ACCOUNT ENGINES IN SHOP.					
Engines in Comparison..	30	13	39		
Number of Shoppings..................	68	37	114		
Total Days Out of Service, Based on Avg. Figures...................	1428	712	2184		
Per Month Figures include 16 Months...	89	45	137		
Per Engine Per Month.................	2.9	3.4	3.5		
At $15.00 per Day, One Engine One Month	$ 43.50	$ 51.00	$ 52.50		
Cost Based on No. Engines on Div. C..	2653.50	3111.00	3202.50	$ 549.00	$ 91.50
			Total Per Month...........	3388.76	2530.49
			Total Per Year.............	40665.12	30365.88
			Total One Engine Per Month	55.55	41.49
			Total One Engine Per Year.	666.64	497.88

Besides this to be considered is life of fire-box. This is about ten years in good water, about three on C Division. Cost of applying a fire-box about $,1000.00. The difference on 55 road engines on Division C would amount to $1,000.00 per month.

The total annual cost of treatment including interest, depreciation, maintenance, chemicals, supervision, etc., is $62,861, or 3.7 cents per 1,000 gallons treated, or 1.1 cents per pound of incrusting solids removed.

The net saving is therefore about $103,910, or 6.1 cents per 1,000 gallons treated, or 1.9 cents per pound of incrusting solids removed.

This net saving reduced to a "per engine" saving on the basis of the total number of 106-ton engines required to evaporate the amount of water treated gives an average annual saving per engine of $458.00.

This average figure compares favorably with the saving per engine reported to result from water treatment on a neighboring line, which is $439.00.

In arriving at the above figures of saving, no consideration was given to the following benefits of water treatment, which, though more or less intermediate, are generally recognized to be large:

(a) Improvement in road performance of locomotives by reducing failures and interruptions to traffic due to leaky flues.

(b) Saving in engine time and enginehouse labor for washing out boilers brought about by removal of the suspended matters in many natural waters by treatment.

(c) The reduction in number of locomotives required for a given traffic due to improved road performance.

These latter benefits will be found to offset many times the foaming troubles that are always present in the alkali districts of the Western lines, and which are aggravated by treatment.

(3) RECENT DEVELOPMENTS IN PUMPING MACHINERY.

A large amount of information has been gathered on this subject and considerable work has been accomplished, but the Committee wishes, at this time, to report progress only. The subject has not been developed sufficiently to report otherwise, and the Committee asks for further time in which to make final report on this subject.

CONCLUSION.

Your Committee respectfully submits the following conclusion:

The report on Subject (2) is submitted as information only. It is intended to give the Association a brief outline of the developments of water-softening on railways since this subject was studied by the Water Service Committee in previous years. Particular reference is given to the relation of the problem of water softening to railway operation.

Respectfully submitted,

COMMITTEE ON WATER SERVICE.

Appendix A.

CORROSION TESTS ON IRON AND STEEL.

The resistance to corrosion of iron and steel plates has been the subject of considerable study and discussion by the Water Service Committee for several years with the view to determining the most suitable and most lasting material for steel water tanks. Following is a report prepared by Mr. J. L. Campbell, Vice-Chairman of the Water Service Committee, on a series of tests of various metals conducted by him, outlining their relative resistance to corrosive influences.

(NO. 1.) TEST OF THREE GRADES OF METAL—CONDUCTED FOR NINE MONTHS ENDING MARCH 1, 1913.

(1) Six pieces of 1/16 in. x 1 in. x 2 in. of ingot iron manufactured by the American Rolling Mill Company, Middletown, Ohio.

(2) Six pieces 1/16 in. x 1 in. x 2½ in. of tank steel manufactured by the La Belle Iron Works, Steubenville, Ohio.

(3) Two pieces ¼ in. x 6 in. x 6 in. of copper-bearing steel manufactured by the Carnegie Steel Company.

The typical analysis of the ingot iron is given by the manufacturers as follows:

	Per cent.
Sulphur	.020
Phosphorus	.005
Carbon	.010
Manganese	.025
Silicon	.005
Oxygen	.030
Nitrogen	.004
Hydrogen	.001
Copper	.060

The tank steel is probably ordinary Bessemer or Open-Hearth steel.

The copper-bearing steel is Open-hearth, the manufacturers giving the copper content as varying from .45 to .60 and the carbon from .12 to .22.

All of the samples tested were ungalvanized plate.

Three samples each of the ingot iron and tank steel were buried in soil in a shallow vessel, the soil being kept approximately in the condition of wet soil in lowlands, where the precipitation is heavy, a considerable drying out of the soil being occasionally allowed. The remaining three samples of each were likewise buried and treated in coal cinders. One sample of the copper-bearing steel was likewise tested in the soil and the other sample in the cinders.

The analysis of the soil is as follows:

	Per cent.
Water of hydration	7.64
Silica (refined)	52.78
Oxide of aluminum (Al_2O_3)	17.94
Oxide of iron (ferrous oxide, FeO)	5.56
Oxide of Manganese (MnO)	.05
Calcium oxide (CaO)	6.30
Magnesium oxide (MgO)	1.44
Oxides of sodium and potassium	5.30
Sulphuric acid (SO_3)	.42
Phosphoric acid (P_2O_5)	.18
Chlorine (Cl.)	.05
Carbonic acid (CO_2)	2.91
	100.57

The analysis of the cinders is as follows:

	Per cent.
Volatile matter	15.70
Combustible matter (fixed carbon)	23.02
Silica (refined)	33.55
Oxide of iron (Fe_2O_3)	7.71
Oxide of aluminum (Al_2O_3)	11.04
Calcium oxide (CaO)	4.25
Magnesium oxide (MgO)	.82
Oxide of manganese (MnO)	.29
Oxides of sodium and potassium	3.26
Chlorine (Cl.)	.02
Sulphuric acid (SO_3)	1.30
Phosphoric acid (P_2O_5)	.09
	101.05

Phosphorus ....0.040 per cent.

The weight of the samples was carefully determined at the beginning and at the end of the test. The final weight was determined after the metal had been carefully and uniformly cleaned of loose rust.

In the soil, the loss by corrosion per square inch of exposed surface was as follows:

	Grams.
Ingot iron	4.19
Tank steel	4.18
Copper-bearing steel	.17

In the cinders, the loss was as follows:

	Grams.
Ingot iron	6.23
Tank steel	7.43
Copper-bearing steel	.38

Apparently, copper is a valuable alloy in producing steel plates to have high corrosive resistance.

(NO. 2.) TEST OF SEVEN SAMPLES OF IRON AND STEEL—BEGINNING MAY 1, 1913.

In the tests beginning May 1, 1913, seven samples of iron and steel were selected, as follows:

No. 1, Charcoal iron,
No. 2, Open-hearth steel,
No. 3, Open-hearth steel containing 0.40 per cent. of copper,
No. 4, Open-hearth steel containing 1.00 per cent. of copper,
No. 5, Ingot iron,
No. 6, same as No. 3, except as to preliminary surface preparation as hereinafter described,
No. 7, same as No. 4, except as to preliminary surface preparation as hereinafter described.

Each sample contained four pieces. The dimensions of the samples were as follows:

No. 1, 1/8 in. x 2 in. x 2 in.
No. 2, 1/8 in. x 2 in. x 2 1/4 in.
No. 3, 1/8 in. x 2 in. x 2 1/2 in.
No. 4, 1/8 in. x 2 in. x 2 3/4 in.
No. 5, 1/8 in. x 2 in. x 3 in.

The dimensions of sample No. 6 are the same as No. 3 with one corner cut off for identification.

The dimensions of sample No. 7 are the same as No. 4 with one corner cut off for identification.

In the following analyses, the figures in the first column are as given by the manufacturers, and in the second column, as given by S. W. Parr, Professor of Applied Chemistry, under the direction of A. N. Talbot, Professor of Civil Engineering, University of Illinois.

No. 1, Charcoal iron.

		Per cent.
Carbon	No analysis	0.041
Manganese		0.205
Phosphorus		0.049
Sulphur		0.032
Copper		0.00
Silicon		0.033

No. 2, Open-hearth steel manufactured by the Carnegie Steel Company, analyzing as follows:

	Per cent.	Per cent.
Carbon	0.15	0.144
Manganese	.037	0.394
Phosphorus	0.037	0.038
Sulphur	0.037	0.039
Copper	Trace	0.00
Silicon	0.00	0.036

No. 3, Open-hearth steel manufactured by the Carnegie Steel Company, analyzing as follows:

	Per cent.	Per cent.
Carbon	0.12	0.141
Manganese	0.38	0.418
Phosphorus	0.020	0.037
Sulphur	0.032	0.028
Copper	0.40	0.43
Silicon	0.00	0.021

No. 4, Open-hearth steel manufactured by the Carnegie Steel Company, analyzing as follows:

	Per cent.	Per cent.
Carbon	0.15	0.139
Manganese	0.45	0.492
Phosphorus	0.023	0.038
Sulphur	0.033	0.034
Copper	1.00	0.98
Silicon	0.00	0.033

No. 5, Ingot iron manufactured by the American Rolling Mill Company, analyzing as follows:

	Per cent.	Per cent.
Carbon	0.012	0.030
Manganese	0.025	0.180
Phosphorus	0.006	0.017
Sulphur	0.028	0.056
Copper	0.042	0.00
Oxygen	0.035	0.00
Nitrogen	0.004	0.00
Silicon	Trace	0.014

No. 6, Quality, manufacture and analysis the same as No. 3.

No. 7, Quality, manufacture and analysis the same as No. 4.

Five corrosive mediums were selected, as follows:

No. 1, Clean sand.

No. 2, Clay soil, to which 5 per cent. of salt by weight was added.

No. 3, A mixture of equal parts of white and black alkali soils.

No. 4, Bituminous coal cinders.

No. 5, Cooling water in the overflow tank from the furnace water jackets of the Copper Queen Consolidated Mining Company, Douglas, Ariz.

Analyses of these corrosive mediums are as follows:

No. 1, Sand.

	Per cent.
Silica	82.31
Oxide of aluminum	9.44
Oxide of iron	2.98
Calcium oxide	1.86
Magnesium oxide	.45
Oxides of sodium and potassium	3.18
Oxide of manganese	Trace
	100.22

No. 2, Clay soil plus 5 per cent. salt.

	Per cent.
Water	5.89
Silica	54.34
Oxide of aluminum	14.33
Oxide of iron	3.71
Calcium oxide	5.10
Magnesium oxide	2.15
Oxides of sodium and potassium	10.17
Oxide of manganese	.11
Sulphuric acid, combined	.95
Chlorine, combined	2.83
Carbonic acid, combined	2.05
Phosphoric acid, combined	.16
	101.79

No. 3, White and black alkali soil.

	Per cent.
Water	5.10
Silica	48.46
Oxide of aluminum	8.76
Oxide of iron	2.00
Calcium oxide	9.45
Magnesium oxide	1.37
Oxides of sodium and potassium	11.10
Oxide of manganese	.04
Sulphuric acid, combined	9.64
Chlorine, combined	3.64
Carbonic acid, combined	2.26
Phosphoric acid, combined	.06
	101.88

No. 4. Cinders.

	Per cent.
Volatile matter	5.44
Fixed combustion carbon	24.60
Silica	41.06
Oxide of aluminum	24.76
Oxide of iron	1.54
Calcium oxide	1.60
Magnesium oxide	.42
Oxides of sodium and potassium	1.22
Oxide of manganese	.02
Sulphuric acid, combined	.50
Chlorine, combined	Trace
Phosphoric acid, combined	.07
	101.23

No. 5. Water in settling tank.

	Per cent.
Alkalinity in $CaCO_3$ parts in 100,000	21.00
Hardness in grains per U. S. gallon	3.50
Total solids	57.88
Silica	1.17
Iron oxide and alumina	0.47
Calcium carbonate	0.40
Magnesium carbonate	0.42
Sodium carbonate	14.00
Sodium sulphate	16.80
Sodium chloride	25.20

The sand, clay soil, alkali soil and the cinders were placed in aluminum pans, each pan being 4 in. deep, 11 in. wide and 16 in. long in the clear. The pans are numbered 1, 2, 3 and 4, and the settling tank at Douglas, No. 5, corresponding to the numbers designating the corrosive mediums contained by the pans. These pans are kept on the balcony of one of the south windows of the seventh floor of the office building of the El Paso & Southwestern Railroad Company, El Paso, Tex. They are exposed to sunlight and air, and the materials in them are periodically saturated with water, thereby being alternately wet and comparatively dry, duplicating in a general way service conditions of iron and steel buried in the ground with a light covering.

In each pan, one piece of each sample of iron and steel, No. 1 to No. 7, inclusive, is placed, with the exception of pan No. 5 at Douglas, in which samples Nos. 6 and 7 were not placed. The pieces are buried in the corrosive medium by forcing them down edgeways to the middle of the depth of the pan, the pieces standing side by side about two inches apart. As this places one piece of each sample of iron or steel in each pan, it makes the corrosive test strictly comparable throughout for all the corrosive mediums.

Each piece of each sample of iron or steel was prepared for beginning the test by carefully filing off all surface oxidation until only clean, bright metal showed over all surfaces of the pieces, including the edges, with the exception of samples Nos. 6 and 7. The original surfaces of samples Nos. 3, 4, 6 and 7, containing copper, were covered with a distinct copper colored oxidation. This oxidation was left on Nos. 6 and 7 to determine its effect in resisting corrosion, as compared with samples Nos. 3 and 4, from which the surface oxidation was completely removed before beginning the tests.

After being prepared as above, each piece of each sample was weighed on a metric scale measuring to one centigram. All pieces of all samples were then immediately immersed in the corrosive mediums as described. At the beginning of the test, it was decided to clean and weigh the samples at the end of each three months' period, and the loss in weight in grams per square inch of exposed surface was chosen as the unit for corrosive comparison. The test is now complete for the second three months' period, and the results are available for the first six months. The test will be continued, but preparation of the report of the Water Service Committee renders it necessary to consider the results to date.

It has been found that the corroded samples may be thoroughly cleaned of the corrosive action, leaving the clean metal, by immersing the samples in a 10 per cent. solution of ammonium citrate, and this method of cleaning has been adopted. In this connection, and at the first cleaning, a clean piece of uncorroded iron was also immersed in the solution in order to determine if the latter itself would produce any loss of weight in the metal. Subsequent weighing of this control piece shows that there is no such loss, and the ammonium citrate appears to be a satisfactory medium for cleaning.

In the following tables, the corrosion is measured in loss of weight in grams per square inch of exposed surface and edges, as follows:

Pan No. 1. Clean Sand.

Sample.		Loss in 3 months.	Loss in 6 months.
No. 1.	Charcoal iron	0.41	0.96
No. 2.	Carnegie plain O. H. steel	0.42	0.86
No. 3.	Carnegie 0.4 per cent. copper, O. H. steel	0.45	0.87
No. 4.	Carnegie 1.0 per cent. copper, O. H. steel	0.45	0.90
No. 5.	Ingot iron	0.43	0.87
No. 6.	No. 3 not filed	0.34	0.90
No. 7.	No. 4 not filed	0.31	0.84

Pan No. 2. Clay soil + 5 per cent. salt.

Sample.		Loss in 3 months.	Loss in 6 months.
No. 1.	Charcoal iron	0.13	0.34
No. 2.	Carnegie plain O. H. steel	0.14	0.32
No. 3.	Carnegie 0.4 per cent. copper O. H. steel	0.20	0.44
No. 4.	Carnegie 1.0 per cent. copper O. H. steel	0.14	0.34
No. 5.	Ingot iron	0.16	0.41
No. 6.	No. 3 not filed	0.13	0.35
No. 7.	No. 4 not filed	0.14	0.32

Pan No. 3. White and black alkali soils.

Sample.		Loss in 3 months.	Loss in 6 months.
No. 1.	Charcoal iron	0.06	0.13
No. 2.	Carnegie plain O. H. steel	0.06	0.14
No. 3.	Carnegie 0.4 per cent. copper O. H. steel	0.06	0.14
No. 4.	Carnegie 1.0 per cent. copper O. H. steel	0.06	0.15
No. 5.	Ingot iron	0.07	0.16
No. 6.	No. 3 not filed	0.04	0.12
No. 7.	No. 4 not filed	0.04	0.10

Pan No. 4. Cinders.

Sample.		Loss in 3 months.	Loss in 6 months.
No. 1.	Charcoal iron	0.76	1.23
No. 2.	Carnegie plain O. H. steel	0.89	1.38
No. 3.	Carnegie 0.4 per cent. copper O. H. steel	0.78	1.34
No. 4.	Carnegie 1.0 per cent. copper O. H. steel	0.78	1.21
No. 5.	Ingot iron	0.71	1.23
No. 6.	No. 3 not filed	0.43	0.93
No. 7.	No. 4 not filed	0.58	1.18

Pan No. 5. Water in overflow tank from furnace water jackets.

Sample.		Loss in 3 months.	Loss in 6 months.
No. 1.	Charcoal iron	1.68	2.188
No. 2.	Carnegie plain O. H. steel	1.62	2.172
No. 3.	Carnegie 0.4 per cent. copper O. H. steel	1.82	2.310
No. 4.	Carnegie 1.0 per cent. copper O. H. steel	1.77	2.255
No. 5.	Ingot iron	1.39	1.880

Your attention is directed to results on samples Nos. 6 and 7 in pans Nos. 1 to 4, inclusive, from which it appears that the copper oxidation on the surface, as compared with the identical samples Nos. 3 and 4, but with the oxidation removed from the latter, protected samples Nos. 6 and 7 for three months, but this protection appears to have disappeared at the end of six months. This may throw some light on the high resistance shown by the copper-bearing samples of the test for 1912, referred to above.

There is another thing to be considered in the first test. The tank steel and ingot iron were of small dimensions, but the sample of copper-bearing steel was much larger. This may have modified the conditions of covering and corrosion in the small pans used.

In contrast to the wide difference in favor of copper-bearing steel in the first test, you will observe that the figures of the test for the current year fail to show marked superiority for any sample. Perhaps the most significant figures are those showing the relative corrosion of samples Nos. 2, 3 and 4, as they are of the same grade of steel, made by the same manufacturer, and are presumably identical in quality, the difference in copper content excepted. In regard to the addition of the copper, we quote from letter of the manufacturer, as follows:

"In regard to the addition of copper, would say that the heats are made up as far as possible with copper scrap and any deficiency in the copper content is made up by adding the requisite amount of metallic copper to the bath in the open hearth furnace about fifteen minutes or half an hour before tapping. The copper, therefore, has ample opportunity to become evenly distributed in the steel, particularly by the mixing action which takes place when the steel runs from the furnace into the ladle."

It will be observed that the corrosion of the ingot iron is substantially the same as the other samples, except in pan No. 5, containing the water from the overflow tank of the furnace water jackets at Douglas, Ariz. Of this water, Mr. Stuart W. French, General Manager, Copper Queen Consolidated Mining Company, says: "We have found that the water is extremely corrosive in our water jackets up to a temperature of say, 150 deg. Fahr. Above that temperature it seems to have little action. It is good water for our boilers, but in all cold water pipes and water jackets, where the water is more or less cool, pitting action is very strong."

The analysis of this water is given above. The steel water jackets of the furnaces mentioned require frequent renewal on account of the corrosion specified by Mr. French. It was for this reason that this water was also selected as one of the corrosive mediums in this test. The corrosive action of this water appears to be somewhat similar to that of an acid, and it will be observed that, while the corrosion of the ingot iron in the other corrosive mediums is not materially different from the other samples, it shows considerably less corrosion in the water, which conforms with its known ability to resist the sulphuric acid test.

The corrosion of all samples in the clean sand is greater than in the clay and alkali soils. Rather the reverse would be expected, especially in the alkali soil. This may be partially due to the fact that, while the sand is porous and allows a comparatively free circulation of air, the clay and alkali soils are very close grained and practically exclude the air.

REPORT OF COMMITTEE VI—ON BUILDINGS.

MAURICE COBURN, *Chairman;*
G. W. ANDREWS,
J. P. CANTY,
O. P. CHAMBERLAIN,
D. R. COLLIN,
C. G. DELO,
C. H. FAKE,

M. A. LONG, *Vice-Chairman;*
C. F. W. FELT,
G. H. GILBERT,
A. T. HAWK,
H. A. LLOYD,
P. B. ROBERTS,
W. S. THOMPSON,

Committee.

To the Members of the American Railway Engineering Association:

The Committee on Buildings held two meetings during the year, one at Chicago immediately after the convention and one at Buffalo in December. There were also several meetings of Sub-Committees.

The following subjects were assigned to the Committee by the Board of Direction:

(1) Present principles covering design of inbound and outbound freight houses.

(2) Report on the advantages and disadvantages of the various designs of freight house and shop floors.

(3) Report on methods of heating, lighting and sanitary provisions for medium sized stations.

Reports on subjects (1) and (2) follow.

Progress is reported on subject (3).

The Committee has also in preparation a report on rest houses.

The following summary of the last report on Roofing is to replace the present conclusions regarding that subject in the Manual.

ROOFING.

The following statement summarizes some of the important points in the report on Roofing, pp. 839 to 878, Vol. 14 of the Proceedings. For detailed information, reference should be had to that report.

In selecting a roofing there should be considered:

(1) Chance of leaks, due to character of construction.

(2) Probable life, including chance of damage by the elements and by wear from other causes.

(3) Fire-resisting value.

(4) Cost of maintenance.

(5) First cost.

The important materials may be classified as follows:

Bituminous substances, applied with felts made of rags, asbestos or jute.

Clay and cement products and slate.

Metals.

They are laid in two general types: That for a flat roof, cemented together, as a coal-tar pitch and gravel roof or as an ordinary tin roof; and that for a steep roof, laid shingle-fashion.

BITUMINOUS MATERIALS.

The common bituminous materials are:

Coal-tar pitch (the heavier distillates of bituminous coal).

Various asphalts (bitumens found naturally in the solid state).

Various petroleum products.

Various animal and vegetable residues.

Their peculiar value lies in the fact that they are practically insoluble in water, that they are elastic, adhesive, and comparatively stable.

Coal-tar pitch is easily affected by heat and cold, is not acted upon at all by water, is easily worked, and, if properly protected, is very stable. It should ordinarily be used as it comes from the still "straight run," of a consistency suitable to the climate and to proper application.

Water-gas tar pitch, a by-product in the manufacture of water gas, which is enriched by gas from petroleum oils, resembles coal tar. It is inferior to coal-tar pitch for roofing purposes, and materials made from it should only be accepted in the low-priced products. It has more value as a saturant of felts than as a coating.

The asphalts are unsuitable for use in their natural state. They are ordinarily fluxed with products of petroleum.

The petroleums found in this country vary considerably, and grade roughly in quality, according to location from East to West. The California oils, with their asphaltic base, furnish materials especially valuable for roofing.

The blowing of air through a heated still of certain petroleum products produces "blown oils," which, while somewhat lacking in adhesive properties, are not easily susceptible to atmospheric changes and are valuable especially for roofing coatings.

A single asphalt fluxed with a single oil is for most purposes a crude and unsatisfactory material. To secure the best results for any desired purpose, several oil and asphaltic substances must ordinarily be compounded. This requires skill and experience. Those properly made are for certain conditions invaluable, particularly for ready roofing, for which tar products are not suited.

The asphalt and petroleum products are not so readily affected by heat and cold as is coal-tar pitch, and lesser amounts of them are necessary to get good results. They are more expensive, require more skill in handling, and, when protected, some at least are to some extent liable to lose their life by drying out of the oil fluxes. Unprotected, they do much better than does coal tar.

FELTS.

The bituminous substances are used with felts whose qualities considerably affect the roofing. The ordinary felt is made of rags, mainly cotton. "Wool Felt" is a misnomer. Asbestos felts, as compared with the rag felt, act less as a carrying medium for the bitumens, but rather as a protection to the layers of bitumen. They are not suited for use with coal-tar pitch, but are not injured by hot asphalt. They are more expensive than rag felts, but have some peculiar and valuable qualities. Burlap made from jute decays easily when not protected. It is used in a few ready roofings with rag felts to increase their tensile strength, the need of which is not generally agreed to.

BUILT-UP ROOFS.

The bituminous roofings come ready to lay, or can be built up on the roof, using layers of saturated felt, mopped with pitch and properly protected.

The built-up roof is especially valuable for flat surfaces. It can be made as heavy as desired and if properly laid and of good materials, gives a roofing which by long experience has been shown to be economical and efficient. Where the roof is to be subjected to wear and where the character of the construction warrants the expense, flat tiles or brick should be used as a protective coating to the roofing instead of gravel or slag.

For the flat roof built under average conditions, coal-tar pitch is recommended in preference to asphalt products. It is more easily handled, requiring less skill, and while more material is necessary, it is still cheaper and in our opinion more certain results can usually be expected from its use when laid by the average contractor. The large amount of material, while heavy, has insulating value. Good results, however, can be expected from built-up roofs using good asphalt compounds where laid by skilled workmen.

When the slope of the roof is over three inches to the foot, the application of a built-up roof becomes more difficult for both coal-tar and asphalt, it being harder to get even mopping and there is more chance of accident for the men. The desirable straight run coal-tar pitch cannot be used, it being necessary to add some stiffening material which is supposed to somewhat affect the life of the pitch. This must not be done except under supervision skilled in such work, and especial care must also be taken in the selection and application of the stone or slag coating.

Built-up roofs with a ready roofing for the coating sheet are proposed by various manufacturers. They should have their best value for steep slopes.

The advantages of a coal-tar pitch built-up roofing are such that it is recommended that where a permanent roof is desired and where the character of the structure allows, that the building be so designed as to allow its use. A flat roof makes an economical structure and has small fire hazard. A pitch of from one-half to one inch to the foot is better

than anything steeper. With proper materials and application a life of from fifteen to twenty years can be expected with a flat roof.

No contracts should be made for a built-up roof without a complete and positive specification including flashings, and the contract prices should not be less than those of the materials specified, plus a reasonable amount to cover the cost of laying and profit. Thorough inspection of workmanship and material is recommended.

READY ROOFING.

The ready roofing has better value for the steeper roofs than for those of small pitch. It averages much cheaper than the built-up types. Most kinds to get a fair life require occasional recoating. For flat slopes they are hard to lay absolutely tight, and they are not economical for a permanent structure, but on slopes of from three inches to the foot up, their use is more justifiable.

Ready or prepared roofings are recommended for use on small, temporary and other buildings, where the cost, considering maintenance, of more expensive roofings is not justified. They are also of value for steep slopes where a built-up coal-tar cannot be used, and for locations where the skilled labor necessary for a built-up roof is not available. The steeper the slope the greater their relative value and the wider their economical field. The heavier varieties are, in general, the more desirable because of their chance for longer life and their greater fire-resisting value. In making selections the reliability of the manufacturer, service tests and the cost should be governing factors.

On the steeper slopes the use of ready roofing shingles properly reinforced so as to prevent curling up at the corners and fraying on the exposed edges and laid shingle-fashion is growing. They are supposed to give better results than the rolled goods, but cost more. They would seem at least to be worthy of investigation.

SLATE AND TILE.

Slate makes a good roof if of good quality and properly watched. It breaks easily and cannot be walked on without danger to the slate.

Tile of good quality gives good results. It is not so tight as slate, but does not break easily. It has architectural value, and its use is growing, with improvement in the product and in the variety of colors.

Slate and tile of suitable quality, properly protected and fastened, can be recommended on roofs with a pitch of six inches to the foot or over, where expense is not the governing feature, and where they aid in producing the desired architectural effect, except that where there is much chance of driving snow, eight inches to the foot should be the flattest slope allowed.

ASBESTOS SHINGLES.

Shingles of asbestos and Portland cement are of value. They have some elasticity and can be driven down tight.

WOOD SHINGLES.

Wood shingles are not now desirable for a railroad structure.

CEMENT TILE.

Small cement tile are not considered of much value, being brittle. Large cement tile reinforced, laid without sheathing directly on the purlins are in use on shops and freight houses and seem to have considerable merit. Glass can be introduced into them, avoiding the expense of skylights. We are not ready to recommend them for plastered or heated buildings or offices where an occasional slight leak would be disastrous.

METAL ROOFINGS.

Metallic roofings with steel as a base are not recommended for general use on permanent buildings. They require continual maintenance.

Galvanizing of steel seems to be well worth the expense. Tests of lead covered steel sheets indicate good results. Large sheets of corrugated galvanized steel can sometimes be used economically where the building is not to be heated.

Small metallic shingles of either copper, tin, galvanized steel plate or specially pure iron are not recommended for general use. They are very light in weight and serve a purpose, particularly in the dry climate of the Southwest.

In using metals, every effort should be made to secure those of good quality. The pure irons have value. Their virtues have perhaps been overstated, but they are not expensive, and experience seems to indicate considerable economy by their use as a substitute for wrought-iron and steel.

Copper, lead, zinc and Monel metal are used for roofing, but they are not of value for ordinary railroad structures.

GENERAL.

In the laying of all roofings thoroughness in preparation of flashings and work around openings is of vital importance.

To get a satisfactory roof there must be a stable structure, careful attention must be given to the design of gutters, and with some types particularly, there must be systematic inspection and regular repairs. In buying a roof its fire resisting qualities, to a considerable extent depending on the quantity of material as well as its quality, are of great importance. A building covered with a heavy coal-tar pitch and gravel roofing is a better fire risk than one covered with corrugated steel sheets, or with a light ready roofing.

The practice of depending merely upon guarantees in selecting roofings cannot be trusted to secure proper results.

It does not pay to put a cheap roof on a good building.

The annoyance and indirect expense occasioned by leaky and short-lived roofs are rarely compensated for by any possible saving in first cost.

PRINCIPLES COVERING DESIGN OF INBOUND AND OUTBOUND FREIGHT HOUSES.

The following report on Freight House Design is presented for publication in the Manual, and is intended to replace the conclusions relating to inbound and outbound freight houses now in the Manual. (See p. 395, under Yards and Terminals.)

The economical handling of less-than-carload freight at terminals is a problem that is giving a great deal of concern. We know (approximately) the cost of handling a ton of freight a mile by train, but it is almost impossible to figure the cost per ton mile for trucking and handling unclassified freight at the freight house. To quote from an article in the Engineering News, March 3, 1910, by Charles Whiting Baker: "The cost of terminal handling in all cities is so great compared with the cost of moving a train or a vessel when started on its journey, that the latter can be ignored." Freight house design should receive serious consideration.

In outlying districts, where fire hazard is not great and business is not large, and the building laws will permit, frame freight houses having wood floors on joists, studding covered with wood sheathing or metal siding, and wood rafters and sheathing covered with appropriate roofing, are fairly satisfactory and cost less than any other sorts. Floor for this type should ordinarily be designed to carry 250 lbs. per sq. ft.

With such construction there should be ventilation beneath the floor, but the access to the space under the house should be prevented to avoid the accumulation of rubbish and increased fire hazard.

But even where a frame house is to be used, it is better practice to use a filled concrete foundation, eliminating some fire hazard and decreasing maintenance charges.

Where the laws prohibit frame structures and the value of freight stored is considerable and it is necessary to build freight houses of so-called fireproof material, floors should be placed on a fill between foundation walls, and the exterior walls should be of masonry or steel frame covered with metal siding. Roof trusses, framing, etc., can be of wood, covered with appropriate roofing, but to provide better fire protection, fireproof construction may be used.

Fire walls of brick or other non-combustible material should be located so as to conform to the requirements of the underwriters. The strictest practice limits the area between firewalls to 5,000 sq. ft. This especially applies to houses with no outside platform. In wide houses, this locates the walls rather close together for economical operation. Fire walls should in no case be more than 200 ft. apart.

Doors in fire walls should be as limited in number as possible, no one door opening should exceed in area 80 sq. ft. and all should be equipped with automatic fire doors.

Where non-fireproof construction is used, inflammable parts of the structure should be covered with fireproof material for a distance of at

least 5 ft. on either side of the fire wall. This refers especially to overhanging roofs.

Where but a single house is needed, a width of from 30 to 40 ft. is good practice.

When the amount of freight handled is sufficient to justify it, separate houses for inbound and outbound freight are desirable. When these are provided, the outbound house should be narrow, not more than 30 ft. wide, and the inbound 40 to 70 ft. wide, it being considered expensive operation where a house is in excess of 70 ft. in width.

A platform 8 to 10 ft. wide, along the track side of the house, avoids the necessity of considering the location of doors in spotting cars on the track next to the house, and also eliminates the necessity of keeping an aisle-way inside the house on the track side. It should be at least 8 ft. wide, to give sufficient room for two trucks to pass.

The distance from the center of the nearest track to the face of the platform or freight house should not be less than 5 ft. 9 in. where tracks are on tangent.

The top of rail should be 4 ft. below the floor or platform level at the track edge, where refrigerator cars are not to be handled in any quantity. With occasional refrigerator cars, the doors can be opened before the cars are set.

Where refrigerator cars are to be handled regularly, the height should not be more than 3 ft. 8 in., this conforming to the recommendations of the M. C. B. Association. (See Proceedings for 1911, Vol. 45, page 728.) The alternative of spacing tracks at least 7 ft. from platforms is usually expensive at important terminals.

The platform should be protected by an overhanging roof, not greater than the width of the platform, and at least 10 ft. above the platform level.

Where state laws permit, protection over the cars is often used. This should be at least 17 ft. above the top of rail and should preferably extend to within 18 in. of the middle of the car. This will allow walking on the top of cars.

There should also be an overhanging roof or other protection on the team side to protect goods while being unloaded, the overhang to be at least 4 ft. and preferably more, 12 ft. being needed to give protection from a driving rain.

Freight houses without outside platforms would seem desirable in some localities, especially in northern climates, where there is considerable snow and sleet, as these houses can be entirely closed, except for that part of the house where the freight is being received or loaded. At some points where ample track room is not available, the elimination of the outside platform gives better results.

With this type it is necessary to leave more trucking space inside the house longitudinally the full length of the building. With the house congested with freight, it is difficult to keep the aisleways from being

crowded up so that it is almost impossible to get through with a truck that is loaded with any large packages. This causes delay and confusion.

On the street side, the floor of the inbound house should be from 3 to 4 ft. above the street grade, depending on the type of trucks in use. At the outbound house the height should not exceed 3 ft.

To assist truckers, the floor of the inbound house should be sloped toward the street, approximately 1 in. in 8 ft., this being for the house proper. An outside platform on the track side should slope approximately 1 in. toward the tracks for drainage.

For the outbound house, the floor should slope from the street to the edge of the platform alongside the car not more than 1 in. in 8 ft.

Several kinds of doors are satisfactory, counterbalance lift (either folding or not), rolling shutters and parallel sliding.

It is advantageous to have as much door opening on the team side as possible, and with all types of doors except the last, all of the house can be opened except for the space occupied by posts.

With the parallel sliding doors, not more than half of the space can be opened up. They are all right on the track side.

Without the outside platform continuous doors should be used, so that an opening can be obtained at any point opposite a car door.

Where an outside platform is provided, a door in each panel is sufficient. Considering the average length of cars and economy in framing, 22 ft. is a good panel length.

It is advantageous to have the floor entirely free from posts; but in houses approaching 50 ft. in width, the saving made by using posts becomes considerable, and great enough to offset the advantages due to their omission.

On account of light weight merchandise being piled high on trucks, it is desirable to have the edge of the eaves at least 14 ft. above the level of the driveway, where local conditions will permit.

As all freight trucked into the house and cars must pass through the car door, the height of the freight-house door need be little greater than the car door. All doors should be at least 8 ft. high. On the team side a greater height might at times be convenient.

Natural light should preferably be provided in the sidewalls above the doors. Skylights in the roof are expensive to maintain and ineffective, as is also glass in canopies or on any plane approaching the horizontal.

Artificial light is needed for operation at night and during the late afternoon in the winter, and, wherever possible, electricity should be used, with wires run according to the specifications of the National Board of Underwriters. One or more lines of lights should be run the full length, inside the house, and one line over outside platforms.

Another circuit should be run along the face of the platform wall parallel to the track, with outlet boxes not over 40 ft. on centers, with socket arrangement for push plug for use in attaching an extension

cord to hang inside the car to provide light for loading on dark days and evenings during the winter season. The need of other outside lights on the train side is questionable.

The type of lights will depend somewhat on the height of the ceiling. All lights should be stationary and operated in circuits from conveniently located panel-boards. The circuits should be carefully planned, so as to allow maximum economy in use of lights.

Where water pressure is available there should be provided for fighting fire standpipes and hose racks not more than 150 ft. apart. By putting them on the fire and end walls they are thought to be more accessible and less liable to be blocked by freight than if located at other points, but by putting them about 40 ft. from the end of each section, fewer hose connections are necessary to cover the entire station. By putting them 100 ft. apart, 50 ft. of hose will be sufficient for each connection, more than this being somewhat inconvenient to handle. As there is no heat in the house, the valve controlling the water supply should be located below the frost line and controlled by a stem, with a hand wheel above the floor. The valve should be located in a pit, so as to be readily accessible for repair or renewal. It should be drained into the pit, and this in turn be connected to the sewer. A 2½-in. standpipe of wrought-iron should be run up to approximately 8 ft. above the floor, and to this should be attached a hose rack, equipped with 50 ft. of 2-in. rubber-lined linen hose.

In houses where electricity is available, there should be over each hose rack a small red light to designate the location of the fire-fighting apparatus, this light to be kept burning at all times.

Chemical extinguishers should be provided in addition to the hose and standpipes. As they are put out of service by freezing, some provision should be made for replacing them or keeping them warm. Tanks containing a solution of calcium chloride are used successfully.

Where a watchman is needed, a watchman's clock system, with a registering clock in the freight office and stations located at various places throughout the freight houses, should be installed.

In outbound houses sufficient scales should be provided so that all the freight can be weighed. From 50 ft. to 80 ft. apart is good practice. In inbound houses where little of the freight is weighed, scales should be placed at least one in each section. The scales should have a minimum capacity of four tons. A successful dial scale expedites the handling of freight. Stalls for checkers should be located at least one in each section. These should be approximately 4 ft. 6 in. by 4 ft. 6 in., with a shelf along the back and drawers beneath. Sometimes they are left entirely open in front, and sometimes are closed up, and heated, depending on local conditions. Some roads make their checkers' stalls portable, so as to allow them to be moved in case of a special congestion of freight at certain points, but this is not ordinarily considered necessary.

In inbound houses a room should be provided to house "over, short and damaged freight;" this be enclosed so that it can be kept locked.

In large layouts, particularly where there is considerable transfer business, a room should be provided for repairing broken packages, such as crates, boxes, barrels, etc.

In large houses a separate office should be provided for the foreman. If this can be an elevated structure, it will save floor space.

In large houses the general office for the clerks and the private office for the agent should be provided by a second story over the inbound house, and in the second story should also be a space for files and stationery cases, toilets and locker facilities for clerks. This all should as far as possible be in view from the desks of the agent or chief clerk. The cashier and his clerks should ordinarily be located on the first floor.

Where possible, it is preferable to have the clerks' and agent's offices, the toilet room, etc., for the freight handlers and draymen, the room for "over, short and damaged freight," and the cooperage room for repairing broken packages, etc., all in one section. In the larger terminals provision may be wanted to care for perishable freight, and when it is provided, it should also be located in this section.

The basement should house the heating plant, with room for coal, and is sometimes a good place for toilets for the freight handlers and draymen, and for locker and lunch rooms for the freight handlers.

Where both outbound and inbound houses are arranged in the same layout, a transfer platform is usually included. One of the best designs for covering these platforms in a butterfly shed, with the post located in the center on the platform. Where this design is used, the platform should not be less than 12 ft. wide, to provide room for trucks between the posts and the cars.

For loading and unloading agricultural implements and other large, bulky packages, platforms should be built, usually as extensions to the inbound and outbound houses, with ramps on the ends of these platforms. The extension platform should be at least 8 ft. wide and, if possible, 16 ft. wide, especially if covered. A stub end track butting against a platform with a ramp is valuable.

Where no gantry crane is provided in the freight yard, a stiff leg or pillar crane should be provided on the end of the extension platform.

It is not good practice to put downspouts inside the house, and in placing them outside they should be properly protected.

On the team side of all freight houses a fender should be provided to protect the walls from the wagon wheels. A good type is one made up of an 8-in. by 10-in. timber set on brackets, with a spacer or separator to keep the timber approximately 2 in. away from the wall, so that dirt will filter through and not collect on the fender.

In large cities it is frequently advisable to build the inbound houses eight to ten stories high, using the ground floor for handling freight and the balance of the structure for storage, to be leased to shippers. Most of the material stored will not be affected by heat or cold, but provision should be made for cold and warm storage where conditions warrant.

This report does not cover freight piers.

FREIGHT HOUSE FLOORS.

The following report on shop floors contains detailed information and diagrams applicable to freight house floors, and can be considered as supplementary to the report of last year on that subject.

SHOP FLOORS.

The essential requirement of a shop floor is a good hard wearing surface that is level, smooth, easy on the feet, easy to truck loads over and capable of carrying heavy loads. Different typical types of construction of shop floors are illustrated by the following diagrams:

CINDER OR GRAVEL FLOOR.—Fig. 1 is a type of floor in general use, one that is best adapted for blacksmith shops and foundries. It is made by filling in the space between foundation walls, preferably with sand or gravel, and bringing the filling up to the required grade, thoroughly compacting it as it is placed. The filling should be well flooded, rolled and tamped. A five to ten-ton roller should be used where possible.

The minimum depth of the finished floor should be 8 in. and if the top surface of the ground is soft, it should be removed below this depth. For a top wearing surface, hard screened cinders or stone screenings should be used to a depth of about 2 in., and this should be thoroughly wet down and rolled to a firm hard surface. Where clay is available it often can, with advantage, be mixed with the top surface and rolled into place. This makes a hard and more compact surface. Crude oil also, when mixed with the top surface, tends to harden it, and helps to prevent the wearing surface from becoming broken up.

This type of floor is often used where an inexpensive floor is required, or where on account of a heavy fill inside of foundation walls, a more expensive floor would fail, on account of settlement.

This type is not well adapted for trucking, and often an industrial track about two feet wide with small push cars or a close-planked runway may be desirable where the most material has to be moved. Special foundations are necessary for all machinery.

PLANK FLOOR ON CINDER OR GRAVEL.—This type of floor, illustrated by Fig. 2, is often found desirable where a heavy fill inside of foundation walls is required, where settlement may occur, and where the type of floor shown in Fig. 1 would not answer on account of the volume of trucking required, or on account of the necessity of gathering up and saving scrap material, as in a machine shop.

It consists of planking, spiked to sleepers resting on the filled material between the foundation walls. The filling, preferably sand or gravel, should be settled as mentioned in connection with Fig. 1, and should be brought up to within 9 in. of the finished floor grade. On this should be placed 6 in. of cinders, gravel, or other material of a porous nature, in the top surface of which 4-in. by 6-in. sleepers are embodied, spaced about 3 ft. centers. They should be laid with running broken joints.

This makes a fairly good working surface, which will last at least four years, at which time all settlement should have taken place in the filling, and a better type of floor can be used. Long leaf yellow pine will last longer than short leaf yellow pine, but will cost more. Fir and hemlock will longer resist decay than will short leaf yellow pine, but they will not wear as long, and are not as good as long leaf yellow pine. Special care should be taken to have the sleepers and plank thoroughly seasoned. For this reason it often is advantageous to get the lumber early on the site of the work, stack it, and allow it to season. Additional life may be obtained, if desired, by creosoting the sleepers, or both sleepers and plank. A cinder bed under the sleepers will give a little longer life than sand or gravel.

Special foundations are necessary for all machinery, and where jacking is done.

Wood Block Floors.—Wood block floors shown in Fig. 3 are often used, and have these advantages:

They can be easily repaired, are easy to work and truck on, and do not damage falling tools. They need a concrete base to distribute heavy loads which may bear on a few blocks only.

The filling between foundation walls is done as in Fig. 1, and includes a 6-in. bed of compacted cinders. On the cinders is laid a 6-in.

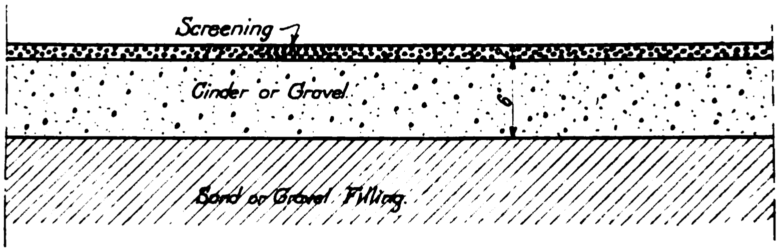


Fig. 1—Cinder or Gravel Floor, Especially Suitable for Blacksmith Shop, Foundry and Boiler Shops.

course of 1:3:5 concrete. Steel reinforcement may often be placed in the concrete to advantage, particularly over soft spots in the filling, or where heavy loads are apt to be placed. The reinforcement should be placed either near the top or bottom surface of the concrete, depending upon local conditions. Sand should be spread over the concrete, and brought with a board or template to a uniform thickness which, when compacted, will amount to one inch.

On the sand bed place the wood blocks, which should be of an even thickness of at least 4 in. The blocks should be cut across the grain so that they can be laid with the ends of the fibre exposed to wear. They should be uniform in width but may be variable in length, although blocks of a uniform length can be laid quicker, and more cheaply.

Wood blocks should be creosoted, and can be made from any material suitable for such treatment. Generally, however, the blocks are of short leaf yellow pine, although long leaf yellow pine blocks give the greatest wear.

The blocks should be laid with the fiber vertical, and with close joints, with at least a two-inch lap. Expansion strips one inch in thickness should be placed every 50 ft. across building and at the sides of the building, or at any break in the floor surface. The blocks should be tamped, or rolled to an even surface, joints filled to within one inch of top surface with sand, and the balance of the joints filled with No. 2 street pitch. Immediately after placing the pitch there should be spread hot dry sand or gravel over the blocks to take up surplus pitch.

Creosoted planks are sometimes used in place of the concrete base. The resulting floor is not nearly as good as one with a concrete base, and is generally equally costly.

Special concrete foundations are necessary for heavy machinery, but for small machinery the foundations may be built up from the concrete base of a size as may be required for the setting of the machine.

Scrap lumber (oak and yellow pine) is often used for shop floor blocks. The mill can take cuttings and condemned lumber, and saw it up at odd times. Consequently such blocks cost practically nothing for material and very little for labor. Such floors are often laid directly on filling or on plank, but they do not last over 4 or 5 years, and care must be taken to provide more expansion joints than with creosoted blocks.

TEMPORARY FLOOR.
FIG. 2—PLANK FLOOR ON CINDER OR GRAVEL.

Hexagonal blocks are sometimes used. They should be not less than 5 in. nor more than 7 in. deep and all blocks for one job should be of the same size. Blocks of this type have no particular advantage except that they are more stable, as they have more friction on the side surfaces and are not so easily tipped up at the corners.

A wood block floor with a concrete base is generally fully as expensive as any good type of floor, and often has to be relaid due to buckling.

ASPHALT BLOCK FLOORS.—Asphalt blocks, about 4 in. by 12 in. by 4 in., are sometimes used to advantage, as they come on the job all ready, and

can be laid like wood blocks or like brick. They do not need expansion joints nor does the laying of them require any skilled supervision. They do not heave, they stay smooth and wear slowly without chipping, except that where there is continuous dripping of oil, as directly under a vise,

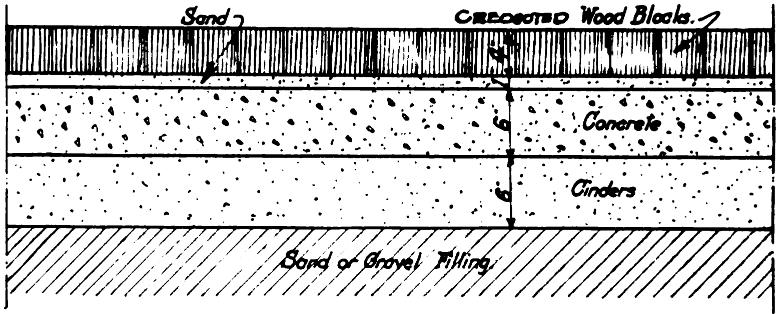


FIG. 3—WOOD BLOCK FLOOR.

they soften and wear faster than at other points. They can be more easily taken up and repaired than other types.

PLANK FLOOR ON CONCRETE.

Fig. 4 shows a wooden floor with a concrete base. It is a good type of floor, as it gives a fine surface either to work on or to truck over. However, it is expensive.

The filling and concrete base should be placed as for a wood block floor, Fig. 3, except that in the top surface of the concrete there should

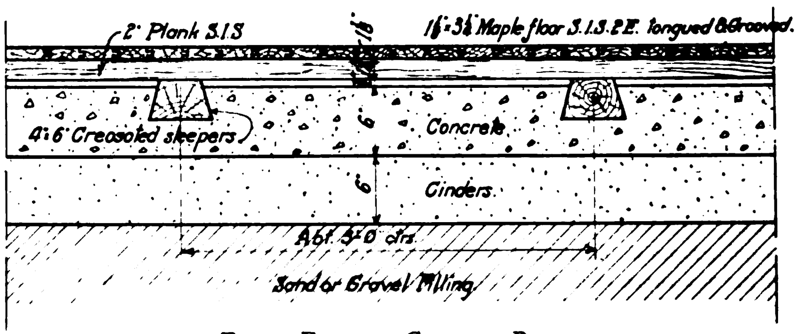


FIG. 4—FLOOR ON CONCRETE BASE.

be embedded 4 in. by 6 in. creosoted sleepers. On these sleepers should be laid 2-in. plank, dressed to even thickness and width. This should be laid with running broken joints. On the planks should be laid a top wearing surface of 1⅛ by 3¼ D. & M. maple flooring with ends matched, laid parallel to the direction of the maximum trucking, and with

running broken joints. The flooring should be end matched and bored for nailing, for which there is little, if any, extra cost. A square edged floor may be used. It costs less, but is not quite so smooth, and will require attention to maintain a good surface. It is especially desirable that the two inch plank should be thoroughly seasoned, and for this reason it should be brought on the site of the work early, stacked, and allowed to season.

This type of floor should ordinarily last from ten to twelve years, and generally fails from dry rot to the sleepers and the underfloor. Additional life may be obtained by creosoting the sleepers and underfloor, and by giving the top surface of the finished floor a good mopping of hot linseed oil which also tends to lessen buckling.

Light machinery may be lag-screwed directly to this floor, and only heavy machinery need be provided with special concrete foundations extending lower than the concrete subfloor.

Wood Floor Set in Tar Pitch.—Fig. 5 shows a wooden floor with a concrete base, the wooden sub-floor being set in a top coat of pitch

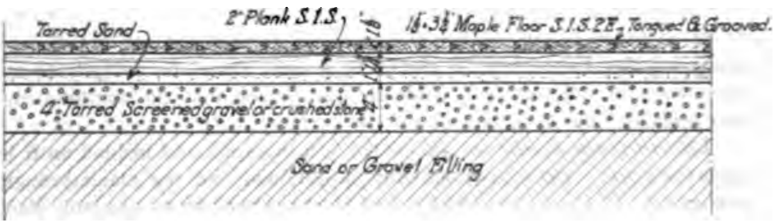


Fig. 5—Tar-Rock Floor.

and sand, spread over the concrete. Either Portland cement concrete or a tar concrete can be used as a foundation. This is a more permanent type of floor than that shown under Fig. 4, unless in the latter case both the sleepers and the underplank be creosoted.

Where Portland cement concrete is used it should be laid as shown in Fig. 4. Where the tar concrete is used, on the compacted filling between foundation walls there is laid 4 in. of coal-tar concrete. The foundation for this concrete should consist of 4 or 6 in. of screened gravel or crushed stone, none of which should exceed 2½ in. in longest dimensions or be less than ¼-in. size, mixed with special subfloor tar (minimum amount stated below), so that it will compact under a roller after being spread evenly in place. It shall then be rolled until the stones do not creep under the roller. The tar for this course may be heated to not more than 200 degrees Fahrenheit, and in cold weather the stone shall be slightly heated, so the tar will mix with the stone and the stone spread evenly. The roller used for this work should weigh not less than

300 lbs. to each foot in length. The amount of tar used in the foundation shall not be less than:

6 gals. for each cu. yd. of 2½ in. to 1 in. crushed stone.
9 gals. for each cu. yd. of 2½ in. to ¼ in. crushed stone.
7 gals. for each cu. yd. of coarse screened gravel.
10 gals. for each cu. yd. of fine screened gravel.

If the mixing is done with a machine, 25 per cent. less tar will be required.

The top coat over the concrete should consist of a fine sand thoroughly mixed with specially prepared tar, in the proportion of not less than 50 or more than 60 gallons of tar to each cubic yard of sand. The sand should be thoroughly dry before mixing, and neither tar nor sand should be hotter than 225 degrees Fahrenheit, when being mixed together. If they are hot enough so a thick white smoke arises from the mixture, five gallons more of tar for each yard of sand should be required. This mixture should be spread evenly 1¼ to 1½ in. (so it will compact to 1-in.) thick over the foundation, leveled with a straight edge and followed closely with the plank.

The top coat mixture may be tested as follows:

If 10 to 20 cu. in. of the mixture at a temperature of 175 degrees to 200 degrees Fahrenheit be placed in a tight vessel to a depth of not less than 1 in. and "patted" it should be deemed that the mixture contains sufficient tar if tar shows on the surface.

Two-in. plank should be laid on the soft material, and bedded on it by hammering until the proper stability is obtained and the plank brought to a proper level and toe-nailed together. If, after hammering any plank is below the proper level, the plank should be taken up and more of the top coat spread on.

In order to insure the use of seasoned plank, it is desirable that the plank should be on the premises as long as practicable before being laid and stacked so that they will have the best opportunity of seasoning, and covered with boards to protect from rain. If green plank are used and covered with a hardwood floor dry rot may result.

Cinders make a foundation in every way as good as stone, but they require at least 15 gallons of this special tar to the cubic yard and far more rolling to properly compact them.

Sand may also be used for the foundation, but at least 20 gallons of tar will be required to each cubic yard, and different special tar must be used. The sand will also need to be heated before the tar will mix with it properly. If desired, either a cinder or sand foundation may be compacted with a rammer instead of a roller.

Light machinery may be attached to this floor without additional foundation, but for heavy machinery special concrete foundation will have to be provided.

Concrete Floor.—Fig. 6 makes a cheap and fairly permanent floor, is easy to truck over, is easily cleaned, is sanitary, and has the

advantage that no special foundations have to be provided, except for the heavier types of machinery. Light machinery is simply bolted to the floor. Industrial tracks may be easily and cheaply installed in the floor with the head of the rail flush with the top surface. This floor, how-

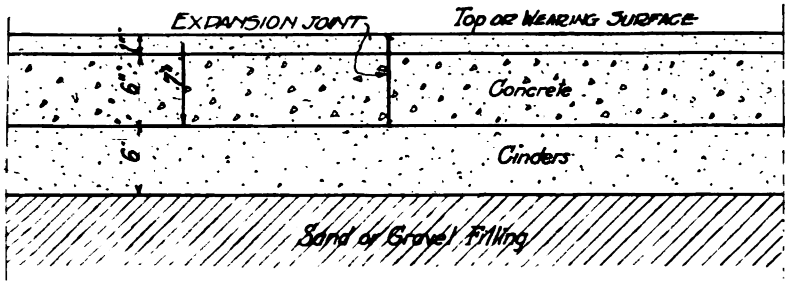


Fig. 6—Concrete Floor.

ever, easily damages falling tools, it is hard to work on, and quite easily becomes worn in spots.

In making it, fill in as for the other types of floors and over the filling spread about 6 in. of hard screened cinders properly compacted. Then lay a concrete floor 7 in. thick of the same concrete proportions given in connection with Figs. 3, 4 and 5, with the exception: that the top or finished surface should be composed of one part Portland cement and 1 to 2 parts torpedo sand, troweled smooth to a sidewalk finish before the base has taken its initial set. Provision must be made for expansion by putting in slabs not over 8 ft. by 16 ft. alternately with small V-joints.

Sometimes granite screenings are used instead of torpedo sand to give additional wearing life. The cost is somewhat increased.

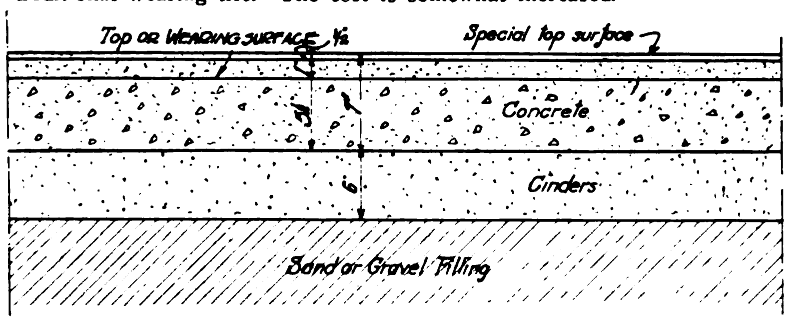


Fig. 7—Special Surface on Concrete Floor.

Ordinary concrete floors are porous and constant wear results in granulation and abrasion, starting holes which rapidly increase in size and gradually make the floors useless. The heavy wear, trucking and constant hard usage make them wear unevenly and break up.

Concrete Floor with Special Finish.—Fig. 7 shows a concrete floor with a special top finish. It is designed to be more lasting than the usual

concrete floor, as the special top is designed to stand harder wear, and to keep floor surface from becoming rough.

There are several special materials on the market that are used for the top finish which give good results.

The special surfaces generally consist of some mineral powder mixed with other substances. When applied the particles of this powder expand, filling the porous places in the concrete and gives a surface of flint-like hardness, making a dustproof, wear-resisting and waterproof floor. One advantage is that this topping can be applied after the base is set without materially hurting its efficiency. These special top dressings may also be used to advantage in patching old damaged concrete floors without renewing them.

Asphalt Floor.—Fig. 8 is considered to be an ideal floor for shops, if properly laid, with the correct materials and mixtures. Experienced supervision must be employed to get the best results. Similar floors are still in service and in fair condition after having been laid 25 years.

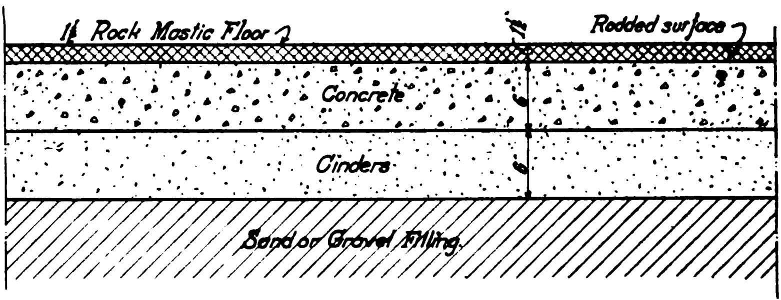


Fig. 8—Rock Mastic Floor.

Floors of this type will outwear others several times. They give the qualities which are desirable in a floor, and are without the objectionable features which have been mentioned in connection with other floors. They are easy to walk on and truck over, and the more the traffic the more dense and durable they become. They do not grind away material under truck traffic, they do not easily wear uneven, do not easily crack or disintegrate, are noiseless and dustless, and can be kept clean by broom or mop, or occasionally by flushing with a hose. They are sanitary, water- and fireproof, and are easily repaired. The filling and concrete subfloors are laid the same as for other types of floors. The top of the concrete should be drawn out under a straight edge struck off, but not troweled.

Mastic blocks should be delivered on the ground plainly marked with name of the brand, and broken up before placed in the mastic boiler. Asphalt flux should then be added and both allowed to cook, until the mastic blocks are entirely melted. Washed torpedo gravel, torpedo sand, crushed limestone or granite, in the proper percentage to give the required hardness, should then be added, and thoroughly mixed into the

mass by iron stirring rods, and the temperature of the mixture brought to 450 degrees Fahrenheit. The material must be constantly stirred to prevent burning and then removed from the kettles in all-iron wheelbarrows or oak buckets, and taken to the work as required.

The gravel or stone must be thoroughly dry before being put into the mastic and should be clean, well-graded material, which contains no particles larger than would pass through a ¼-in. mesh.

Native bitumens do not give as good results as do the imported mastics.

BRICK FLOOR.

Fig. 9 shows a brick floor with a concrete base. Such floors are easily repaired, easily cleaned, sanitary, fairly cheap, but are hard to truck over, hard for men to work on and hard on falling tools. The filling, concrete base and one-inch sand cushion are placed as for a wood-block floor. Over this is laid the brick floor. The bricks should be vitrified, repressed pavers laid edgeways and carefully tamped or rolled

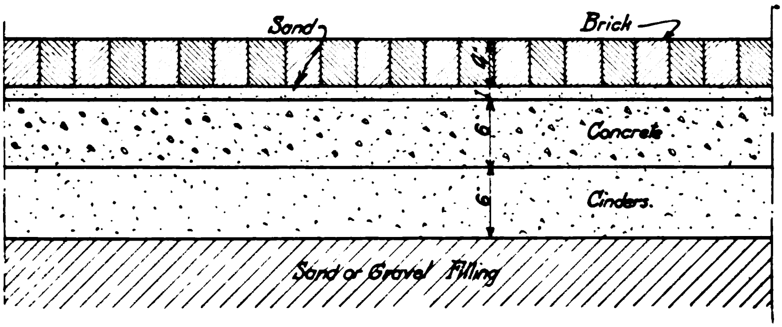


FIG. 9—PAVING BRICK FLOOR.

to insure an even top surface. The intervening space betwen bricks should be filled with Portland cement and sand of a one-to-one mixture, and poured as a thin grout, followed up with a stiffer mixture, and covered over with sand. Expansion joints are necessary, as for creosoted blocks, but the joints need not be so large.

Special foundations for machinery must be provided, as with a creosoted block floor.

CONCLUSIONS.

Your Committee recommends:

(1) That the report on Roofing be adopted and substituted for the matter under that heading now appearing in the Manual.

(2) That the report on Freight House Design be adopted and substituted for the conclusions relating to inbound and outbound freight houses now in the Manual (p. 395).

(3) That the report on Freight House Floors be approved for publication in the Manual. Respectfully submitted,

COMMITTEE ON BUILDINGS.

REPORT OF COMMITTEE III—ON TIES.

L. A. Downs, *Chairman;*
A. M. Acheson,
C. C. Albright,
H. W. Brown,
W. J. Burton,
S. B. Clement,
E. D. Jackson,
H. C. Landon,
F. R. Layng,

G. W. Merrell, *Vice-Chairman;*
E. R. Lewis,
R. J. Parker,
J. G. Shillinger,
G. D. Swingly,
D. W. Thrower,
H. S. Wilgus,
Louis Yager,
E. C. Young,

Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned your Committee by the Board of Direction:

(1) Report on the effect of design of tie plates and spikes on the durability of ties.

(2) Continue study of stresses to which cross-ties are subjected, and determine size required.

(3) Report on economy in labor and material effected through the use of treated ties as compared with untreated.

(4) Continue to compile information as to the use of metal, composite and concrete ties.

The work was divided into Sub-Committees as follows:

(1) R. J. Parker, Chairman;
W. J. Burton,
D. W. Thrower,
A. M. Acheson.

(2) C. C. Albright, Chairman;
H. S. Wilgus,
H. W. Brown,
H. C. Landon,
J. G. Shillinger.

(3) E. R. Lewis, Chairman;
W. A. Clark,
Louis Yager,
S. B. Clement.

(4) F. R. Layng, Chairman;
E. D. Jackson,
G. W. Merrell,
E. C. Young.

(1) THE EFFECT OF DESIGN OF TIE PLATES AND SPIKES ON THE DURABILITY OF TIES.

Your Committee reports progress on this subject and submits its partial report for the benefit of the Association.

There were 37 inquiries sent out to the principal railroads in the United States asking the following information:

"(1) How long have you used tie plates?

"(2) Give briefly the dimensions of plates, and state whether they are flat-bottom, longitudinal or cross-ribbed, etc.

"(3) Are your plates applied to ties primarily for the purpose of prolonging the life of the tie, or are they applied to assist in holding gage?

"(4) What has been your experience with plates having longitudinal ribs over 3/16-in. deep, with reference to tie failures?

"(5) What has been your experience with plates having cross-ribs or claws over 3/16-in. deep with reference to tie failures?

"(6) What has been your experience with plates having longitudinal ribs 3/16-in. or less with reference to tie failures?

"(7) What has been your experience with plates having cross-ribs 3/16-in. or less with reference to tie failures?

"(8) What has been your experience with flat-bottom plates with reference to the mechanical wear of the tie? Has this wear, if any, been on track having screw spikes?

"The following Committe report has been outlined and your criticism of the same is requested. In making reply, kindly indicate wherever statements are based on observation or information gathered from actual experience:

"(a) Plates with deep ribs or claws cut the tie so as to admit moisture and decay. The deep ribs or claws are not necessary to hold the plate in position and are undesirable.

"(b) Flat-bottom plates used with cut spikes become loose and the looseness results in mechanical wear of the tie. They are satisfactory when used with screw spikes.

"(c) Plates with cross-ribs not over 3/16-in. deep do not seriously damage the tie and at the same time do not become loose enough to rattle and cause mechanical wear when used with ordinary cut spikes.

"(d) Plates less than 7 in. wide for use with softwood ties cut into the tie sufficiently in some cases to determine the life of the tie.

"(e) The plates should be of sufficient thickness to avoid cupping on either side of rail. This thickness depends on the projection beyond the rail, the amount of traffic, the kind of tie and the rate of deterioration from rust, etc.

"(f) Screw spikes prolong the life of ties over that obtained with cut spikes.

"(g) Where treated ties are used, all boring should be done previous to treatment.

"(h) Ordinary driven cut spikes, by breaking down the structure of the wood for an inch or so around the spike, facilitate decay at the point where greatest strength in the tie is required. In case of treated ties, this introduction of decay below the treatment may defeat the purpose of the treatment.

"(i) The breaking down of the structure of the wood, with the use of cut spikes is, to a considerable extent, avoided where the spike is driven

in a bored hole. Spikes so driven have at least the same holding power as spikes driven without boring. Where spike holes are to be bored and cut spikes used, the diamond-pointed cut spike is preferable, because of the greater ease with which it follows the hole."

Of the 37 requests there were 29 replies received, and 27 of them agree to the following ideas:

(a) Plates with deep ribs or claws cut the tie so as to admit moisture and decay. The deep ribs or claws are not necessary to hold the plate in position and are undesirable.

(b) Flat-bottom plates used with cut spikes become loose and the looseness results in mechanical wear of the tie. They are satisfactory when used with screw spikes.

(c) Plates with cross-ribs not over 3/16-in. deep or other independent fastenings that will hold them to the tie, do not seriously damage the tie and at the same time do not become loose and cause mechanical wear when used with ordinary cut spikes.

(d) The width of the tie plate is an element to determine the mechanical wear of the tie, less than 7 in. wide, for use with softwood ties cut into the tie sufficiently in some cases to determine the life of the tie.

(e) The plates should be of sufficient thickness to avoid cupping on either side of rail. This thickness depends on the projection beyond the rail, the amount of traffic, the kind of tie and the rate of deterioration from rust, etc.

(f) Screw spikes prolong the life of ties over that obtained with cut spikes.

(g) Where treated ties are used, all boring should preferably be done previous to treatment.

(h) Ordinary driven cut spikes, by breaking down the structure of the wood for an inch or so around the spike, facilitate decay at that point where greatest strength of the tie is required. In the case of treated ties, this introduction of decay below the treatment may defeat the purpose of treatment.

(i) The breaking down of the structure of the wood, with the use of cut spikes, is, to a considerable extent, avoided where the spike is driven in a bored hole. Spikes so driven have at least the same holding power as spikes driven without boring. Where spike holes are to be bored and cut spikes used, the diamond-pointed cut spike is preferable, because of the greater ease with which it follows the hole.

See Appendix A for report on "Comparative Holding Power of Spikes, Chisel Point versus Diamond-Point."

See Appendix B for report on "Holding Power of Spikes, Cut Spikes versus Screw Spikes."

See Appendix C showing photographs on effect of design of track spikes and tie plates on the durability of ties.

(3) ECONOMY IN LABOR AND MATERIAL EFFECTED THROUGH THE USE OF TREATED TIES COMPARED WITH UNTREATED TIES.

PREFACE.

The information presented in the following report has been collected from different parts of Canada and the United States.

Though possibly the latest, it is by no means the last word on the comparative life and cost of treated and untreated ties. Since it depends on the experience of the officers of railways in divers parts of this continent, its results must be understood to be very general, and suitable for use as guides only, in arriving at an estimated annual cost of ties in any individual case.

It is evident that in every such problem local conditions must remain the primary factors.

With the completion of the many well-ordered tests now instituted, it is hoped that the zones of information may be so narrowed that fair averages of tie-life and cost in any State may be made available within the next two decades.

The ever-increasing demand for tie timber and the ever-decreasing supply have created the necessity for treating timber not suitable for ties in its natural state.

If the total annual cost to the railways of treated ties can be brought within the annual cost of untreated ties, these timbers, hitherto unusable, become of service.

The economy in labor resulting from use of treated as compared with untreated ties depends largely on the cost and frequency of tie renewals and therefore on the comparative life of the ties.

It is considered most desirable to present both labor and material economies in cost per tie per annum.

GENERAL.

The comparative life and cost of untreated and treated cross-ties involve many variable factors.

Few American railways have used treated ties long enough to obtain complete data on length of life, while records of life of untreated ties are not all reliable.

The service life of ties depends on conditions under which the timber is grown and manufactured as well as the conditions to which the tie is subjected in the track.

The species of timber, the portion of the tree from which the tie is cut, the season of the year when cut, the extent of curing, the method of laying in track, the excellence of roadbed and ballast, the drainage, tie plates, rail base, spike, splice, axleload, density of traffic and maintenance; —all these conditions have their individual effects. Treated ties are further affected by the method and kind of treatment, variations in

receptive qualities of different ties of the same kind of timber, and even of individual ties from the same tree.

Climatic conditions exert powerful influence on tie-life, both before and after cutting and before and after putting in track. The Northern latitudes, where seasons of plant growth are short, winters long, and altitudes high, make possible quite different results from those obtained in Southern countries of low altitude and excessive humidity.

Numerous careful tests, now being made, will undoubtedly result in the increase of valuable information along the lines of tie-cost and life.

EARLY HISTORY.

The wide differences in treatment and in traffic conditions in other countries must be considered before applying to local problems the results obtained abroad. Though the treatment of wood with preservatives was in general practice in Europe earlier than in America, we have record of several early experiments along this line in the United States.

In American Society of Civil Engineers Transactions, May 17, 1899, W. W. Curtis reports as follows:

"A street railway in Cambridge, Mass., was laid with spruce stringers and sleepers in 1855. In 1883, 28 years later, the stringers were all worn out, but the President reported that 'many, and, I think, the majority of the sleepers are in good condition to-day.'

"On the Vermont Central Railroad, ties were treated in 1856 to 1860, at which time the plant was abandoned and the entire matter lost sight of until 1879, when an old sidetrack was removed, which had not been in use for several years, and which was nearly covered with earth and grass; still the hemlock ties were then found to be nearly sound after over 20 years.

"On the Chicago, Rock Island & Pacific Railway eight spans of Howe-truss bridges, built in 1860, were still in use and in fair condition in 1882 On this road 2,000 ties of hemlock, pine, tamarack and cedar were laid in 1866. In 1882 about 75 per cent. of the hemlock was still in the track and good for several years longer; the pine and cedar ties had all been removed sometime during the 15 years—the tamarack lasting about as long as the hemlock.

"On the Lehigh & Susquehanna Railroad, L. L. Buck reported in 1883 that he had examined Burnettized maple, beech and hemlock ties laid in 1867-68, which had 'resisted decay almost perfectly. Most of the treated ties appeared good for 7 or 8 years longer.'

"In 1891, 200 tamarack and 200 hemlock ties were treated for and placed in the tracks of the Pittsburgh, Fort Wayne & Chicago Railway. Thomas Rodd, Chief Engineer, says of them (1898):

"'After these ties were put in the track we watched them pretty carefully, and for about 3 years they cut rather more than an oak tie. After that, however, they seemed to cut less than an oak tie, and are to-day in good shape in our main track.'

"In the spring of 1898 two of these ties had decayed, and were removed. An examination after removal satisfied Mr. Chanute that the two ties were from dead trees, and their failure after 7 years' service he attributes thereto."

We are indebted to W. F. Goltra, in his "History of Wood Preservation," Proceedings American Wood Preservers' Association, 1913, for the following information:

"The invention of the steam locomotive and railway gave rise to the necessity for protecting the wooden ties, or 'sleepers,' as they call them in Europe, from decay. From this period may be reckoned the active progress in wood preservation. The treating of railway ties with a preservative of some kind increased rapidly, and very soon the quantity of wood treated in the form of railway ties exceeded that used for all other purposes. This ratio is constantly increasing, and at the present time perhaps 90 per cent. of the wood treated in the United States consists of railway ties.

"Inasmuch as the real active progress in the development of timber preservation did not occur until the advent of railways, and the development of the latter in America was contemporaneous with that of European countries, it may be said that the development of the wood-preserving industry was contemporaneous in all countries. A good many experiments were made in America, based largely, however, upon European experience, from which much data was obtained.

"The first recorded use of treated ties were some chestnut ties treated with chloride of mercury (Kyan's process) and laid on the Northern Central of Maryland in 1838. Some oak ties treated by the same process were laid in track of the Chesapeake & Ohio Railroad in 1840. Presumably both of these were trial lots to determine the value of the process. It is recorded that these ties gave a service of twelve to fifteen years.

"The first treating plant worthy of the name was probably that at Lowell, Mass., built in the year 1848 by the proprietors of the locks and canals at that point. The plant consisted of two wooden tanks, each 50 ft. long, 8 ft. wide and 4 ft. deep, in which the timber was immersed in accordance with the Kyanizing process, using chloride of mercury. Chloride of zinc was also used in treating wood at this plant. It was here used for bridge work in connection with canals and not with railroads. This plant is still in use and is now owned by Otis Allen & Son, of Lowell, Mass.

"The growth of the treating industry in the United States was slow during the following three or four decades, only a few small plants being constructed.

"The Philadelphia, Washington & Baltimore Railroad and the Philadelphia & Reading Railway each built works to treat material with zinc chloride and started to treat their ties, the former in 1863 and the latter in 1867. They found that ties would last against decay, but 'were brittle as a carrot,' caused, of course, by the solution used being too strong, so that the ties were overtreated and had to be removed. However, they were used as fence posts, and it is said they lasted a long time. It is not definitely known what solution the Philadelphia, Washington & Baltimore Railroad used, but that of the Philadelphia & Reading Railway is said to have been 3¼ per cent. strong.

"The Louisville & Nashville Railroad built a treating plant at West Pascagoula, La., in 1875-6. The plant was arranged to treat material by the pressure process with creosote oil. It was built primarily to treat piles, stringer caps and ties used in construction of trestles and docks. Creosote timber was extensively used in the New Orleans, Mobile & Texas Railroad, extending from Mobile, Ala., to New Orleans, La., many important structures having been built of creosote timber from 1876 to 1879. The Louisville & Nashville Railroad acquired control of the road from Mobile to New Orleans in 1880. In 1882 large quantities of creosote piles, stringers and caps were used in construction of trestles and docks of the Louisville & Nashville lines in the city of Pensacola, Fla., and vicinity. The earlier use of creosote piles was more for the purpose of protecting them from attacks of sea-worms or toredo navalis.

"However, in more recent years, large quantities of creosoted piles and sawed timber have been used by the Louisville & Nashville lines when not subject to attack of sea-worms and have been used mostly for economical reasons.

"About 600 longleaf yellow pine ties, which were creosoted at this plant and placed in the track in 1877-1878, remained in the track until June, 1905. The amount of oil injected into these ties is not known, but it is estimated at 15 to 18 lbs. per cu. ft. or 45 to 55 lbs. per tie.

"The Houston & Texas Central Railroad also built a treating plant at Houston, Tex., in 1876, to treat piling and timbers generally with creosote oil.

"It is not to be supposed that every experiment made in this new field was a success. They were frequently dependent upon men without much prior experience in this line, and who, to some extent, were feeling their way. Neither was it known that, where zinc chloride was used successfully in the case of bridge timber, that it could also be satisfactory with cross-ties. It seemed to have been tried in some cases where there was necessity of economy irrespective of other considerations, and failure was not, therefore, a cause for surprise. In the majority of the earlier trials, however, the results were favorable, so that about 1878 several other railways made tests with treated cross-ties with such success that in 1885 the Atchison, Topeka & Santa Fe Railway erected a treating plant at Las Vegas, N. M., and because of continuous operation of the same to 1906 may be considered the pioneer company in its line. It is true this plant was built eleven years later than the Louisville & Nashville Railroad plant at Pascagoula, but it should be borne in mind that this plant was not built primarily for the treatment of railroad ties, as is the case with the Las Vegas plant. The latter plant had two cylinders, and for some years all the ties and timbers were treated by the zinc-tannin process, otherwise known as the Wellhouse. In part of 1890 and all of 1891 and part of 1892 zinc chloride alone was used as a preservative, and from 1900 to date of dismantling of the plant that treatment alone was used.

"The Atchison, Topeka & Santa Fe in 1897 made a contract with the Texas Tie & Lumber Company of the Santa Fe to build a plant at Somerville, Texas, for treatment of their ties with zinc chloride. A second treating plant was also built by the Santa Fe at Bellemont, Ariz., in the same year.

"In 1886 the Chicago, Rock Island & Pacific Railway, which had previously tried the Burnettizing process without success, made a contract with Card & Chanute (later the Chicago Tie Preserving Company) to treat a specific number of hemlock and tamarack ties each year by the Wellhouse process. So satisfied were they with the results that as each contract expired it was renewed from time to time with an increased quantity. Mr. Octave Chanute figured up the average life of these ties treated at the Chicago works by three different methods and found it to be 10 2-3 years.

"In 1887 the Southern Pacific (Atlantic System) began treating Texas soft-pine ties at a leased plant, and in 1891 built one of their own at Houston, Texas. To this company's officials belongs the credit of being the only road having complete record of service given by treated ties from the start. Only the Burnettizing method has been used on that system. So satisfactory were the results that the Pacific System of the same company erected a portable plant in Oregon in 1894 and since then have treated practically all of the ties used on that part of the system.

"The heavy increase in cost of ties of durable quality caused several of the western roads to begin the use of certain woods, the life of which they knew to be very short, but which could be materially lengthened by treatment. Many plants were therefore constructed, either owned by

the railroads themselves or by private concerns who treated under contract.

"In 1899 the Chicago, Burlington & Quincy built a plant at Sheridan, Wyo., for treating lodge-pole pine ties from Wyoming and the Black Hills. The Great Northern Railway built a plant at Kalispell, Mont., in 1901, for treating Montana pine, tamaracks, etc. The Missouri, Kansas & Texas Railway built one at Greenville, Texas, in 1901, and the Mexican Central Railway one at Aguas Calientes, Mexico, about the same time.

"At the end of the year 1903 there were 27 timber-treating plants in the United States.

"Railroad ties constituted fully 90 per cent. of the total quantity of material treated during that period, and fully 95 per cent. of the ties were treated with chloride of zinc and the remaining 5 per cent. with creosote oil. Some of these plants have since been dismantled or moved elsewhere, such as the Las Vegas plant and the Bellemont, Ariz., plant of the Atchison, Topeka & Santa Fe and the three portable plants of the Southern and Union Pacific railways.

"GROWTH OF THE INDUSTRY IN EUROPE AND AMERICA.

"The statistics of European railways relating to number of ties treated from the beginning can only be found in the voluminous and scattered records in various languages which are meager, and difficult to obtain, and the author does not pretend that it is accurate, but it may be of interest to the reader in comparing the figures with those given later for the United States.

"The railway mileage of Europe, January 1, 1909, is reported as 195,521 miles. Of this mileage Germany stood first (34,743), followed in their order by Russia (32,743), France (28,430), Austria-Hungary (24,261), United Kingdom (22,847), Italy (10,070), Spain (9,190), Sweden (7,677), Norway (2,931). European railways use a large number of metal ties and space their ties much farther apart than practiced in the United States, so that there are not so many wooden ties used per mile for maintenance in Europe as in the United States.

"The number of wooden ties treated annually in Europe is about as follows: Germany, 4,000,000; Russia, 2,600,000; France, 3,000,000; Austria-Hungary, 2,500,000; United Kingdom, 2,300,000; Italy, 1,000,000; all other countries in Europe, 1,200,000; total, 16,600,000. Thus the total quantity of ties treated annually in Europe is about one-half the number treated in the United States during the past year or two.

"The total number of timber-treating plants in Europe is between 65 and 70. Approximately 85 per cent. of all wooden ties in use in Europe are treated.

"In the United States the data is more copious and reliable. The author has compiled the accompanying statement from various government reports and publications. The steam railway mileage was obtained from Interstate Commerce reports, the electric and street railway mileage from the Electric Railway Journal of New York, for years 1900 to 1912, inclusive; previous to 1900 figures estimated by the author.

"The number of ties used by steam and electric railways was obtained from Forest Service reports from year 1907 to 1911; previous to 1907 from United States Census reports and estimated by the author. The number of ties treated from 1907 to 1911, inclusive, from Forest Service reports, previous to 1907 from various publications and estimated by the author. All figures for 1912 are estimated.

"The proportion which treated ties formed of the entire number purchased is calculated and given for each year, also number of plants in operation from 1860 to 1912, inclusive, is stated.

"Up to January 1, 1900, approximately 15,000,000 ties were treated in the United States, of which about 14,500,000 were treated with chloride of zinc and 500,000 with creosote oil.

"During the year 1903 the number of ties treated was 9,010,000, of which 8,400,000 were treated with chloride of zinc and 610,000 with creosote oil, and during the year 1905 approximately 14,890,000 ties were treated, of which 13,420,000 were treated with chloride of zinc and 1,470,000, or about 10 per cent., with creosote oil.

"During 1907 and 1909 the largest number of plants were built in the United States, being 12 in the former and 11 in the latter year.

"The proportion which treated ties form to the entire number used has gradually increased from 1 per cent. in 1886 to 24 per cent. in 1912, and we see no reason why these percentages should not increase from year to year until the bulk of them receive a preservative treatment.

"Our supply of timber is fast diminishing. We are consuming it at such a reckless rate that some of us may live to see a day of repentance. Aside from the great economy effected by the use of treated ties and timber, there should be in all of us the spirit of patriotism, which will urge us to husband the resources of our magnificent inheritance of forests."

C. T. Barnum, United States Forest Service, in a paper presented before the Western Society of Engineers, October 6, 1909, entitled "Wood Preservation from an Engineering Standpoint," says in part:

"The practice of preservative treatment will also create a new and increasing market for many timbers not formerly used, and timber consumers will more easily break away from their former custom of adhering closely to a few well-known kinds and disregarding others which may be equally as good in other respects, but lack durability. Moreover, there will be an increasing realization that by the use of cheaper woods properly treated with preservatives, as good or better results can be obtained, together with the reduction of the annual cost. This last item, the saving in dollars and cents, is the all-important factor of wood preservation. As soon as the consumer fully understands that his annual expenses can be actually reduced by these methods, it is only natural to conclude that a strong effort will be made for their adoption.

"Wood preservation is an exceedingly complex subject, and upon considering it many problems arise for solution. There has been a great deal of thought given to it, and it has undoubtedly made rapid strides during the comparatively short time it has been practiced in this country. Nevertheless, it is still far from being on a sound scientific basis. The experiments that have been made show very clearly that each different species of wood, and wood of the same species but differing in the character of growth present an entirely different set of problems. They differ greatly in the receptibility of different preservatives and they differ in the kind of preparation necessary for treatment and in their action in contact with the preservative, and after. The kind and condition of wood to be treated and the conditions under which it is to be used are very important factors in determining the kind of treatment that is best. The effect of the preparation and of the preservative on the mechanical properties of the wood are also very important, and must be carefully considered before any treatment is decided upon. Present practices are now largely determined by the experience derived from preceding years rather than an intimate knowledge of the theory of the subject. This latter feature, however, is most important and is at the present time receiving much deserved consideration.

"LENGTH OF LIFE.

"The length of life of treated timber, like the treatment, depends on a variety of conditions. The kind of wood, kind of preservative used,

the kind of treatment given, and the conditions under which the treated timber is used, all have an important bearing on the length of life. In the Southern states, Louisiana and Texas particularly, a loblolly pine tie untreated will last little more than a year. Ties treated with zinc chloride and placed in a track in the same locality have been removed in three years on account of decay. The life of the same species of timber in one section of the country will not be the same when exposed to the climatic conditions in another section.

"The Forest Service has estimated that proper preservative treatment will increase the life of ties over 200 per cent.

"ECONOMIC CONSIDERATIONS.

"It has been clearly demonstrated that the life of timber in many situations has been increased at least twofold by the use of preservatives, and often the increased life is very much greater. Suppose, for example, that certain timbers put to a certain use will last 5 years without treatment. Disregarding interest charges, it is therefore true that the cost of treatment must be less than the additional cost of new timbers 5 years later, plus the cost of their setting in order to effect a saving. In treating on a large scale the additional cost of any treatment now practiced does not usually exceed the present purchase price of the timber. Therefore, the saving means at the least the cost of resetting the timbers, plus the advance in price of timber, over a period of 5 years.

"With railway ties a wide field for the betterment of conditions exists in the more general introduction of preservative treatment. Formerly, white oak was the most popular and widely used species for this purpose, but in the past 10 years the cost of the oak tie has more than doubled, and railroads have consequently been turning their attention to other species. Thus loblolly and shortleaf pine in the South, hemlock and tamarack in the lake states, lodgepole pine and Engelman spruce in the West, birch in Wisconsin and the New England region, and maple and beech in Michigan, Pennsylvania, New York and Vermont, are gradually attaining recognition and rarely fail, when properly protected from decay and mechanical wear, to give satisfactory results. For example, it has been estimated by the Chicago & Northwestern Railway that the cost of the average untreated hemlock or tamarack cross-tie, when laid for use west of the Mississippi, is 75 cents. The cost of a satisfactory impregnation with zinc chloride is about 12 cents per tie, making the cost of the treated tie 87 cents.

"The annual charge on an untreated tie costing 75 cents is 16.8 cents. For a treated tie costing 87 cents and lasting 6 years, the annual charge is 16.6 cents; lasting 7 years, 14.5 cents; lasting 8 years, 12.8 cents, and 10 years, the estimated life of a treated tie, the annual charge is 10.7 cents. These figures demonstrate that an added life of a single year make the cost of treatment practicable and an added life of 5 years (a conservative estimate) secures a saving of 36.3 per cent. in the annual charge.

"By proper preservative treatment and the prevailing rates of interest, it can be conservatively estimated that the net annual saving for each form treated would be about 3 cents for a tie.

"Wood preservation, then, accomplishes three great economic objects: (1) It prolongs the life of durable species in use; (2) it prolongs the life of inferior and cheaper woods and thus enables the utilization of those inferior woods which, without preservative treatment, would have little or no value; and (3) it reduces the annual charge and renewal charges whenever it is used enabling the money saved to be put to other uses."

DISCUSSION.—BY OCTAVE CHANUTE.

"After an experience of some 24 years in the preservation of wood, I will say that results depend largely upon the thoroughness with which the work is done. When we began work along this line the results obtained were not nearly as good as those we are obtaining to-day, simply because we had not had the necessary experience. We followed at that time the German practice of injecting about one-third of a pound of chloride of zinc to the cubic foot of timber, and an average life of 11½ years was obtained with hemlock and tamarack ties. Since then we have ascertained that the Germans, in their extended experience, have increased the dose to one-half pound of dry chloride of zinc to the cubic foot, and with that we are now obtaining results (only 10 years old, however), which promise a life of 14 to 17 years in the track.

"We also found that in the early days we treated the ties too soon, and did not allow them to be sufficiently seasoned to become entirely saturated throughout with the antiseptic treatment. I feel confident now, with the knowledge we have acquired, that we are going to get results with zinc-treated ties which will compare favorably with, although they will not equal, the results to be obtained with creosote. If creosote be thoroughly injected into wood with the full-cell process, the results which have been obtained in Europe show that a life of 20 to 27 years can be obtained. But there is one element there which does not obtain in this country. The rolling stock on the European railroads is light, the weight per wheel is limited to about 10,000 lbs., while the weight of our modern freight cars is much greater; for instance, a car weighing 49,000 lbs. and carrying 100,000 lbs. will give wheel pressures of about 18,000 lbs. per wheel. Those weights are all producing mechanical wear, so that the ties, whether treated with zinc chloride or creosote, are going to be destroyed by mechanical wear sooner than by decay. Therefore, the problem of preservation also brings up the problem of better track, which I hope will be given due consideration by the engineers of railroads."

FOREIGN PRACTICE.

In a report presented to the American Society of Civil Engineers, May 17, 1889, W. W. Curtis cites the following statistics of German practice in railway tie preservation:

COSTS AND RESULTS OF WOOD PRESERVING FOR THE UNION OF GERMAN RAILROADS FOR 1896

Kind of tie	Cost of crude tie	Treated with Chloride of Zinc					Treated with Tar Oil—Creosoted				
		Absorption in lbs.	Cost of treatment	Total cost	Average duration	Cost per year	Absorption in lbs.	Cost of treatment	Total cost	Average duration	Cost per year
			Cts.			Cts.		Cts.			Cts.
Oak....	$1.49	24.2	13	$1.62	15	10.8	{15.4 {24.3	21 29	$1.70 1.78	24 28	7.1 6.3
Beech..	1.01	34	15	1.16	9	13.0	{66.0 {79.2	50 59	1.51 1.60	30 34	5.0 4.7
Pine....	.84	34	16	1.00	12	8.3	{50.6 {79.2	43 57	1.27 1.41	20 23	6.3 6.1

This is based on a tie 6½ in. by 10 in. by 8 ft. 10 in.

In the "Organ of the Progress of Railroads," series 1897, published in Wiesbaden, there is a table in which the average duration of various ties on the German railroads is given for the zinc treatment and also with tar oil (creosoted). These are:

Oak ties, treated with zinc chloride, 15 years; with tar oil, 24 years.
Beech ties, treated with zinc chloride, 9 years; with tar oil, 30 years.
Pine ties, treated with zinc chloride, 12 years; with tar oil, 20 years.

The contract prices in Germany for Burnettizing are: For pine and beech, 5 cents per cu. ft., and for oak, 4 cents; for treating with zinc-creosote, 6 cents for beech and pine, and 5 cents for oak; for creosoting, 15 cents for beech and pine, and 9 cents for oak. In creosoting, the amount of creosote per cu. ft. is 12 lbs. for pine, 15 lbs, for beech, and 4½ lbs. for oak. It is understood that the oak referred to corresponds to American white oak and not to the American red and black oaks, which will absorb as much as either pine or beech.

In conection with treatment, the ties can have the rail seat dressed and the spike holes bored for about 3 cents per tie.

Below is an abstract of answers of British railways to Mr. Herzenstein in reply to inquiries concerning treatments and life of railway ties. This abstract appears in Vol. XLV, June, 1901, Transactions of the American Society of Civil Engineers, in a report presented by Octave Chanute.

TABLE 1

No.	Railway	Number of sleepers annually renewed	Process of Preservation	Amt. Injected	1894 Report Cost Cts.	Life in yrs.	Cause of Failure
I.	Belfast & N. Counties Ry.	....	Creosoting	1 gal. per cu. ft.	12	15	Splits
II.	Furness Ry.	40,000	"	8 lbs. per cu. ft.	15	15	....
III.	Hall Barnoley Ry.	4,000 to 24,000	"	8 lbs. per cu. ft.	....	.....	....
IV.	Great Eastern Ry.	90,000 to 100,000	"	2½ gal. per tie	16	12–15	Wear
V.	Great Northern Ry.	....	"	0.7 gal. per cu. ft.	13	12	....
VI.	Great Southern & Western Ry.	....	"	3½ gal. per tie	....	.....	....
VII.	London & Northwestern Ry.	300,000	"	30 lbs. per tie	....	16–20	Wear
VIII.	London & Southwestern Ry.	170,000	"	2½ gal. per tie	18	12	Wear and Splits
IX.	London, Tilbury & Southend Ry.	Variable	"	7 to 10 lbs. per cu. ft.	....	25–30	Decay, etc.
X.	Manchester L. & L. Ry	20 per mile	"	10 lbs. per cu. ft.	....	16	40% decay
XI.	Midland Ry.	....	"	....	....	.....	....
XII.	North British Ry.	....	"	1 gal. per cu. ft.	14	.....	....
XIII.	North London Ry.	....	"	28 lbs. per tie	....	15	....
XIV.	Southeastern Ry.	97,000	"	28 lbs. per tie	....	8–9	Wear
XV.	Taff Vale Ry.	17,000	"	1½ gals. per cu. ft.	30	15	Natural causes

TABLE 2.—ABSTRACT OF ANSWERS OF FRENCH RAILWAYS TO MR. HERZENSTEIN

No.	Railway	Number of ties annually renewed	Kind of wood	Process of Preservation	Amount Injected	Cost 1893, Cts.	Life in years	Causes of Failure
XXVII.	State	161,213	Pine	Zinc Creosote	66 lbs. per tie	......	10–15	Decay.
XXVII.	State	....	Oak	Zinc Creosote	9 lbs. per tie	......	.....	....
XXVIII.	Eastern	356,650	Beech	Creosote	60 lbs. per tie	42	25–30	Wear.
XXIX.	Meridional	10%	Oak	None	....	......	.....	....
XXX.	Southern	284,511	Pine	Sulphate of Copper	0.4 lb. dry per cu. ft.	......	8–10	Decay and wear.
XXX.	Southern	....	Oak	Creosote	9.5 lbs. per tie	......	10–15	Since increased.
XXXI.	Northern	285,000	Oak	Creosote	11 lbs. per tie	11	.....	....
XXXI.	Northern	....	Beech	Blythe Process	24 lbs. per tie	21	.....	Going over to straight creosoting.
XXXII.	Western	242,050	Oak	Creosote	11-13 lbs. per tie	......	15–20	Decay and splits.
XXXII.	Western	....	Beech	Creosote	31-33 lbs. per tie	......	18–25	Now inject 44 lbs.
XXXIII.	Orleans	460,000	Oak	Creosote	12 lbs. per tie	......	15	Decay.
XXXIII.	Orleans	....	Pine	Creosote	35-44 lbs. per tie	30	13–16	Decay.
XXXIV.	Paris, Lyon & Mediterranean	700,000	Oak	Creosote	10-11 lbs. per tie	12	12	Decay and cutting.
XXXIV.	Paris, Lyon & Mediterranean	....	Beech	Creosote	26-35 lbs. per tie	18	Prior to 1890	Now copies Eastern.

"Ties prepared by the zinc-creosote process, mostly pine, now last from 12 to 18 years, and creosoted ties, mostly oak, are expected to last from 24 to 28 years. In past time it was not always thus, some beech ties creosoted having perished about as soon as some ties injected with chloride of zinc alone, but the results developed upon the roads in Alsace-Lorraine, where beech ties, creosoted by the French, were found to be sound after 21 years of exposure, have again brought the Germans to favor the use of beech creosoted, there being a surplus of that timber, heretofore disesteemed, in the forests of that country."

The prices paid in Germany for treatment, when reduced to American currency, are shown in tables 3 and 4.

TABLE 3.

	With Zinc Chloride.		With Zinc Creosote.	
	First Class.	Second Class.	First Class.	Second Class.
Timber.	Cents Per Tie.	Cents Per Tie.	Cents Per Tie.	Cents Per Tie.
Pine	15.60	12.00	19.20	14.40
Oak	12.00	9.12	15.60	12.00
Beech	18.80	12.48	20.40	15.36

TABLE 4.

	With Creosote and Drying Oven.		Boiling in Creosote.	
	First Class.	Second Class.	First Class.	Second Class.
Timber.	Cents Per Tie.	Cents Per Tie.	Cents Per Tie.	Cents Per Tie.
Pine	53.76	40.32	56.64	42.00
Oak	26.85	20.16	28.80	21.60
Beech	56.64	42.00	59.28	44.40

These prices are based upon the various amounts of the antiseptics which the different woods absorb, with careful work. As already stated, treatment with chloride of zinc alone has been given up, and boiling in creosote is growing in favor, as computations of annual charges for the renewals exhibit the fact that, notwithstanding the higher cost, impregnation with tar-oil is the most economical, in the long run.

H. F. Weiss, in a paper printed in the Proceedings of the American Wood Preservers' Association, 1913, page 80, table 3, shows the average life of treated ties obtained in service on 100 railways in this and foreign countries. From this table has been compiled the following list of average treated tie life for the different countries:

Germany, Prussia and Austria	18.5 years
France	17.5 years
Great Britain	16.0 years
Switzerland	15.2 years
United States	12.4 years
Average life of treated tie, all countries	16.4 years

AMERICAN PRACTICE OF TIE TREATMENTS.

Of American practice in tie preservation, past, present and future, much might be said about the exact commercialism of treatment processes.

It was early found undesirable to treat ties with a view to longest obtainable life on account of mechanical wear.

It is likewise desirable to provide sufficient preservative to well outlast the mechanical life of the average tie in order to take advantage of that large percentage of ties which lasts longer than the average, due to light traffic, light axleloads and sidetrack service.

A timely note of warning against under-treatment has been sounded by F. J. Angier, Secretary American Wood Preservers' Association, in which he says:

"It is the practice in this country to inject a minimum amount of preservative, or at least to endeavor to inject just enough to counterbalance the life of a tie from the standpoints of decay and mechanical wear. It might prove, however, that we are making a mistake in treating with 'empty cell processes.' Thousands of ties are being treated with small doses of creosote, in many instances ranging from 12 to 20 lbs. per tie, with only a superficial penetration. With many inferior woods now being used for cross-ties the heartwood remains practically untreated, and with the more refractory woods even the sapwood is not entirely impregnated. With such treatment are we not going to be very much disappointed in the life obtained?"

Octave Chanute, in a paper presented before the American Society of Civil Engineers (Vol. XLV, June, 1901), says on this subject:

"It appears that the Europeans are now getting a longer service out of their ties than is obtained in the United States, Mr. Curtis having shown in his paper read before this Society May 17, 1899, that an average life of 10 to 12 years is being obtained by the use of zinc chloride in this country. It would be possible to obtain a life of 15 to 30 years by the use of creosote, but it will be seen from the figures given that this would cost three to four times as much as zinc chloride. Thus, at present prices,

it would cost 45 cents each to creosote according to English practice, and 15 to 16 years' life would be obtained; it would cost about 85 cents each to creosote after the best French or German practice, and 27 to 30 years' life would be obtained in thoroughly-drained ballast; but it would not be economical to spend such sums upon ties costing 20 to 40 cents each untreated, while it is economical to spend them upon ties costing from 90 cents to $1.50 each abroad.

"We must be content, therefore, either to allow our cheap ties to decay in the good old way, or to adopt for the present some of the cheaper and inferior methods which will produce shorter lives than obtained in Europe."

In the past the American railways seem to have nearly doubled the life of ties by preservative processes.

It is believed that the results obtainable from present practice will not give such extended average life. The questions of what we want and how we are to best get it with the materials at hand and the conditions confronting us are only now in a fair way to be answered through the experiments being made.

COST AND LIFE TABLES.

Information received from 16 principal railways of the United States indicate actual costs of tie treatments to 1913 as follows:

Average Cost of Tie Treatment.

Ry. No.	Creosote Company Plant.	Creosote Contract.	Zinc Chloride Company Plant.	Zinc Chloride Contract.	Card Process Company Plant.
1	.283	....	....	....	....
2	.258	....	....	....	....
3	....	.310	....	....	....
4	.250	....	....	....	....
5	....	.324	....	....	....
6	.380	....	....	....	....
7	.235	....	....	....	....
8	....	.235	....	....	....
9	.252	....	....	....	....
10	....	....	.112	....	....
11	....	....	....	.155	....
12	....	....	....	.150	....
13	....	....	.100	....	....
14	....	....	.100	....	....
15	....	....	....	....	.175
16	....	....	....	....	.176
Averages	.276	.289	.104	.152	.175

The above costs include all labor, material, fuel, handling of ties at plant and charges for interest and depreciation in the case of company plants.

In obtaining the following figures, no reports were considered where less than 40 per cent. of the original number had been renewed. To extend the figures beyond the percentage reported renewed, it was assumed that for the remaining percentage the renewals per year were equal to the average renewals for the years reported.

AVERAGE LIFE OF UNTREATED CROSS-TIES.

Deduced from "Statistics of Cross-Ties," p. 360, Vol. 12, Proceedings, A. R. E. A.

Railroad	Kind of ties	Number	State	Year laid	Percentage reported renewed and life	Computed Average Life of 100%
C. I. & S.	Red and White Oak	55,500	Illinois	1899	55.3 at 10 yrs.	9.7 yrs.
C. M. & St. P.	Yellow Pine	7,500	Iowa	1900	41.8 at 10 "	11.1 "
C. R. I. & P.	White Oak	101,700	Texas	1903	92.9 at 7 "	6.1 "
D. & I. R.	Tamarack	7,500	Minnesota	1902	73.6 at 8 "	7.8 "
Erie	Oak	8,605	Ohio	1903	45.9 at 7 "	7.5 "
Ill. Cent.	White Oak	351,600	Iowa	1899	49.5 at 11 "	11.2 "
L. S. & I.	White Oak	57,000	Michigan	1896	99.7 at 14 "	10.7 "
L. & A.	White and Post Oak.	93,900	Louisiana	1903	55.3 at 7 "	7.1 "
L. & N.	White Oak	24,920	Kentucky	1895	100.0 at 13 "	9.5 "
M. H. & L.	Cypress, R. & W. Oak	236,160	Arkansas	1905	69.9 at 5 "	4.3 "
M. & O.	Oak	646,631	Miss. and Ala.	1897	74.7 at 13 "	10.6 "
M. & O.	Pine	646,631	Miss. and Ala.	1897	56.5 at 13 "	12 "
N. Y. C. & H. R.	White, Rock and Red Oak and Chestnut.	150,048	Penn.	1901 2	100.0 at 8 "	5.9 "
P. & R.	White Oak	16,915	Penn	1901	93.8 at 9 "	7.5 "
P. & R.	Oak and Chestnut	5,760	Penn	1897	91.5 at 13 "	11 "
P. & R.	Chestnut	2,816	Penn	1903	83.5 at 7 "	6.4 "
Penn. Lines West	White Oak	127,902	Ohio	1892	100.0 at 14 "	10 "

Average Life............8.7 yrs.
White Oak only..........9.1 yrs.

The growing conservatism of engineers on the subject of the life of untreated ties is noted in answers to inquiries along this line made in 1913 as compared with answers from the same men in 1911, from which the above averages were deduced.

ANNUAL AND COMPARATIVE COSTS OF TIES.

The annual cost of tie maintenance for labor and material is the governing consideration of the railway tie problem. Any change in the prevailing practice must stand the test of monetary economy.

In a general consideration the increased cost of a treated tie is justified when the annual cost of its maintenance in track does not exceed the annual charge of the untreated tie.

The increased life of a treated tie naturally decreases the number of annual renewals, resulting in a decreased labor charge and disturbance to the track and ballast.

The item of decreased track disturbance has a value, an estimate of which has been variously attempted (and by some, valued as high as one-fourth the total cost of surfacing) without definite convincing results. The determination of this factor is so much involved as to almost defy a satisfactory solution; so that it may properly be accounted as an undetermined credit to the use of the treated tie.

The increased initial cost of a treated tie over an untreated tie raises the question of interest charges on the additional expenditure for the period of its life in track; and it is fair to assume that the ultimate economy of treated tie use must cover this interest feature. Numerous methods have been suggested for computing the resultant economy of treated ties over untreated ties, arriving at capitalized values or annual costs per tie. The accuracy of the monetary values arrived at may be questionable; but the results from a comparative standpoint have a direct workable value.

An accurate and interesting economic comparison of "Railway Ties of Different Materials," by Neil N. Campbell, appearing in the Engineering News of September 22, 1910, is quoted below.

The variable factors of initial cost, treatment, labor, tie plates, life, etc., may be considered in this method to obtain results that will disclose fairly the comparative economic features of the problem at hand.

Similarly the problem of the economic aspects of resorting to devices for resisting mechanical wear, or increased cost of treatments to obtain additional tie life may be studied.

"AN ECONOMIC COMPARISON OF RAILWAY TIES OF DIFFERENT MATERIALS.

"By Neil N. Campbell.

"The principal elements that must always be considered in determining the relative merits of different materials used as railway ties are: (1) First cost; which should include the cost in forest, the freightage, handling and distributing, and the cost of placing the tie in the track; (2) life, that is, the time elapsing from the date when the tie is laid to the time when it becomes necessary to renew it; (3) cost of renewals; (4) rate of interest on money; (5) maintenance, or cost of repairs; (6) salvage, or the scrap value of the tie at the close of its life of usefulness. Since the cost of maintenance of ties is practically the same for all kinds, it will be omitted in this consideration. The item of salvage is also extremely small and in most cases is zero or negative; therefore, this also will be omitted, leaving only four elements to be considered; (1) the first cost; (2) life; (3) cost of renewals; (4) rate of interest.

"For example, let us consider two ties: a white oak tie, which costs 68 cents in the track and lasts nine years, and a pine tie, which costs 61.5 cents in the track and lasts six years. On the basis of capitalization, that tie is considered cheapest which under present conditions will require the least amount to install, and the least amount to be set aside at compound interest to reproduce it forever. The capitalization is made up of: (a) The first cost $= C$, (b) the amount at compound interest necessary to produce in interest during the life of the tie its first cost $= C^1$.

$$C^1 = \frac{C}{(1+R)^n - 1}$$

Total capitalization equals

$$C + C^1 = \frac{C\,(1+R)^n}{(1+R)^n - 1} \quad \text{.....................} (1)$$

in which n equals the years of life of the tie, and R equals the rate of interest on money, taken as 4 per cent. Then the total capitalization is as follows:

"White oak tie:

$$\frac{0.68\,(1+.04)^9}{(1+.04)^9 - 1} = \$2.286$$

"Pine tie:

$$\frac{0.615\,(1+.04)^6}{(1+.04)^6 - 1} = \$2.933$$

"On the basis of annual cost that tie is considered cheapest which under present conditions shows the least annual cost. The annual cost

being made up of: (a) The interest on first cost $= I = CR$; (b) the amount that must be set aside annually at compound interest to provide for renewal at the expiration of the life of the tie =

$$A = \frac{CR}{(1+R)^n - 1}$$

"Total annual cost =

$$I + A = \frac{CR(1+R)^n}{(1+R)^n - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

"The annual cost of white oak tie =

$$\frac{0.68 \times .04\,(1+.04)^9}{(1+.04)^9 - 1} = \$0.091$$

"The annual cost of pine tie =

$$\frac{0.615 \times 0.04\,(1+.04)^6}{(1+.04)^6 - 1} = \$0.117$$

"On the basis of equivalent cost, one tie is considered to cost the same as another when the capitalization or annual cost of the one is equal to the capitalization or annual cost of the other, or

$$C^1 = \frac{C(1+R)^n}{(1+R)^n - 1} \times \frac{(1+R)^{n^1} - 1}{(1+R)^{n^1}} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

where C is the cost of a tie of n years' life, and C^1 is the cost of a tie of n^1 years' life.

"Assuming a white oak tie that costs 68 cents in the track and lasts nine years, to find what can be paid for a pine tie lasting six years to show the same merit,

$$C^1 = \frac{0.68\,(1+.04)^9}{(1+.04)^9 - 1} \times \frac{(1+.04)^6 - 1}{(1+.04)^6} = \$0.479$$

"From the foregoing consideration, we see that on the basis of capitalization the white oak tie is the more economical, requiring only $2.286 total capitalization, while the pine tie requires $2.933, showing an advantage in favor of the white oak tie of $0.647. On the basis of annual cost the same is true. The annual cost of the white oak tie being $0.091, while that of the pine tie is $0.117, showing an advantage in favor of the white oak tie of $0.026. Again, on the basis of equivalent cost we see that we can only pay $0.479 for a pine tie lasting six years to show the same merit as a white oak tie lasting nine years, and costing $0.68, while we actually pay $0.615.

"Table 1 shows the average life and cost in track of the ties used on representative railroads all over the United States, having a total mileage of 62,309 miles. It gives the kind of ties used, their average life, their average cost in track, together with the comparative value of each on the basis of capitalization, annual cost, and equivalent cost, using as a basis for comparison a live white oak tie costing $0.68 in the track and lasting nine years. Ties which show an average life of a fraction of a year in the computations were considered to have a life represented by the nearest whole number of years.

"The figures in last column of this table indicate the order of merit of the ties as shown by their capitalization and annual cost, regardless of the kind of timber used or whether they were treated or untreated.

"The lower line in the accompanying diagram represents graphically what we can afford to pay for ties of different life to show the same merit as a white oak tie costing \$0.68 in the track and lasting nine years.

"Table 1 does not take into account the necessity of using tie-plates on any of the ties, but with increase in traffic and heavier rolling stock it becomes necessary to use tie-plates on all softwood ties on curves, whether treated or untreated, and on hardwood ties which are treated. The best practice also recommends that tie-plates should be used on all softwood treated ties on tangent. If this is not done it is impossible to obtain the full life of the ties, as they fail through mechanical wear before they lose their usefulness through decay. Assuming that a live white oak tie will resist mechanical wear as long as it can resist decay, let us compare with it a pine tie on which we have to use a tie-plate. The white oak tie with life of nine years to cost \$0.68; the pine tie with life of six years to cost \$0.615; tie-plates to cost 14 cents each and last for 20 years. Total capitalization of white oak tie (by formula 1):

$$=\frac{C(1+R)^n}{(1+R)^n-1}=\frac{0.68(1+.04)^9}{(1+.04)^9-1}=\$2.286$$

"Total capitalization of pine tie equals:

"(a) First cost in track $=C,=$ cost of pine tie to be renewed every six years, \$0.615; cost of two tie-plates to be renewed every 20 years, \$0.28; total, \$0.895.

"(b) The amount at compound interest necessary to produce in interest during the life of the tie its first cost:

$$=C_1=\frac{C-T}{(1+R)^n-1}.$$

"(c) The amount at compound interest necessary to produce in interest during the life of the tie-plates their first cost:

$$=C_2=\frac{T}{(1+R)^{n^1}-1}$$

"Total capitalization $=C+C_1+C_2=$

$$\frac{C(1+R)^n}{(1+R)^n-1}-\frac{T}{(1+R)^n-1}+\frac{T}{(1+R)^{n^1}-1}$$

where $T=$ cost of tie-plates which last n^1 years, $n=$ life of tie, $R=$ rate of interest on money. Then total capitalization of pine tie $=$

$$\frac{0.895(1+.04)^6}{(1+.04)^6-1}-\frac{28}{(1+.04)^6-1}$$

$$+\frac{28}{(1+.04)^{20}-1}=\$3.448$$

The annual cost of the live white oak tie (by formula 2), $=$

$$\frac{CR(1+R)^n}{(1+R)^n-1}=\frac{0.68\times.04(1+.04)^9}{(1+.04)^9-1}=\$0.091$$

The annual cost of the pine tie equals, (a) the interest on first cost $=CR$, (b) the amount that must be set aside annually at compound interest to provide for the renewal of the tie at the expiration of its life $=$

$$A=\frac{R(C-T)}{(1+R)^n-1}$$

(c) the amount that must be set aside annually at compound interest to provide for the renewal of the tie-plates at the expiration of their life is

$$A_1 = \frac{RT}{(1+R)^{n_1} - 1}$$

Then the total annual cost $= 1 + A + A_1 =$

$$\frac{CR(1+R)^n}{(1+R)^n - 1} - \frac{TR}{(1+R)^n - 1} + \frac{TR}{(1+R)^{n_1} - 1}$$

$$= \frac{0.895 \times .04\,(1+.04)^6}{(1+.04)^6 - 1} - \frac{.28 \times .04}{(1+.04)^6 - 1}$$

$$+ \frac{.28 \times .04}{(1+.04)^{20} - 1} = 0.138.$$

"From these examples we see that the white oak tie shows considerable advantage over the pine tie, requiring only $2.286 capitalization, while the pine tie with a tie-plate requires $3.448. A similar advantage is shown when the two are considered on the basis of annual cost. The annual cost of the white oak tie being $0.091, against $0.138 for the pine tie.

TABLE 1.—COMPARATIVE VALUES OF TIES OF DIFFERENT MATERIALS.

Material	Treatment	Average life, years	Cost in track	Capitalization	Annual cost	Equivalent cost	Order of Merit
White Oak.....	None............	9.0	$0.680	$2.286	$0.091	$0.680	25
Other Oaks.....	None............	6.0	0.625	2.981	0.119	0.479	30
Other Oaks.....	Zinc chloride....	11.0	0.730	2.083	0.083	0.801	23
Other Oaks.....	Creosote........	15.0	0.827	1.860	0.074	1.017	15
Pine............	None............	6.0	0.615	2.933	0.117	0.479	29
Pine............	Creosote........	15.0	0.750	1.687	0.067	1.017	3
Pine............	Zinc chloride....	8.0	0.710	2.636	0.106	0.616	28
Cypress........	None............	10.0	0.540	1.664	0.066	0.742	2
Cypress........	Creosote........	17.5	0.950	1.952	0.078	1.112	19
Cypress........	Rueping.........	15.0	0.810	1.822	0.073	1.017	6
Chestnut.......	None............	9.0	0.655	2.202	0.088	0.680	24
Gum...........	None............	5.0	0.550	3.089	0.124	0.407	31
Gum...........	Rueping.........	15.0	0.810	1.822	0.073	1.017	7
Gum...........	Creosote........	17.5	0.855	1.757	0.070	1.112	4
Hemlock.......	Rueping.........	15.0	0.810	1.822	0.073	1.017	8
Hemlock.......	Creosote........	17.5	0.950	1.952	0.078	1.112	20
Locust.........	None............	12.0	0.700	1.865	0.075	0.858	16
Locust.........	Rueping.........	17.0	0.860	1.767	0.071	1.112	5
Locust.........	Creosote........	20.0	1.000	1.840	0.074	1.243	14
Hickory........	Rueping.........	15.0	0.810	1.822	0.073	1.017	9
Hickory........	Creosote........	17.5	0.950	1.952	0.078	1.112	22
Beech..........	None............	4.0	0.550	3.787	0.151	0.330	32
Beech..........	Rueping.........	15.0	0.840	1.889	0.076	1.017	18
Beech..........	Creosote........	17.5	0.950	1.952	0.078	1.112	21
Tamarack......	Rueping.........	15.0	0.810	1.822	0.073	1.017	10
Maple..........	None............	4.0	0.550	3.787	0.151	0.330	33
Maple..........	Rueping.........	15.0	0.810	1.822	0.073	1.017	11
Birch..........	None............	4.0	0.550	3.787	0.151	0.330	34
Birch..........	Rueping.........	15.0	0.810	1.822	0.073	1.017	12
Catalpa........	None............	20.0	0.600	1.104	0.044	1.243	1
Redwood.......	None............	10.0	0.850	2.620	0.105	0.742	27
Elm............	Rueping.........	15.0	0.810	1.822	0.073	1.017	13
Fir.............	None............	7.0	0.620	2.582	0.104	0.549	26
Fir.............	Zinc chloride....	15.0	0.830	1.867	0.075	1.017	17

TABLE 2.—COMPARATIVE VALUE OF DIFFERENT TIES, USING TIE-PLATES.

Material	Treatment	Average life, years	Cost in track including two tie plates	Capitalization	Annual cost	Equivalent cost	Order of Merit
White Oak.....	None............	9.0	$0.680*	$2.286	$0.091	$0.680	7
Other Oaks.....	None............	6.0	0.625*	2.981	0.119	0.479	26
Other Oaks.....	Zinc chloride....	11.0	1.010	2.596	0.104	0.801	25
Other Oaks.....	Creosote........	15.0	1.107	2.375	0.095	1.017	18
Pine............	None............	6.0	0.895	3.448	0.138	0.479	31
Pine............	Zinc chloride....	8.0	0.990	3.151	0.126	0.616	30
Pine............	Creosote........	15.0	1.030	2.202	0.088	1.017	4
Cypress........	None............	10.0	0.820	2.179	0.087	0.742	2
Cypress........	Creosote........	17.5	1.230	2.467	0.099	1.112	21
Cypress........	Rueping........	15.0	1.090	2.337	0.093	1.017	8
Chestnut.......	None............	9.0	0.655*	2.202	0.088	0.680	3
Gum...........	None............	5.0	0.550*	3.089	0.124	0.407	27
Gum...........	Rueping........	15.0	1.090	2.337	0.093	1.017	9
Gum...........	Creosote........	17.5	1.135	2.272	0.091	1.112	5
Hemlock.......	Rueping........	15.0	1.090	2.337	0.093	1.017	10
Hemlock.......	Creosote........	17.5	1.230	2.467	0.099	1.112	22
Locust.........	None............	12.0	0.980	2.370	0.095	0.858	17
Locust.........	Rueping........	17.0	1.040	2.282	0.091	1.112	6
Locust.........	Creosote........	20.0	1.280	2.355	0.094	1.243	16
Tamarack......	Rueping........	15.0	1.090	2.337	0.093	1.017	12
Beech..........	None............	4.0	0.550*	3.787	0.151	0.330	32
Beech..........	Rueping........	15.0	1.120	2.404	0.096	1.017	20
Beech..........	Creosote........	17.5	1.230	2.467	0.099	1.112	23
Hickory........	Rueping........	15.0	1.090	2.337	0.093	1.017	11
Hickory........	Creosote........	17.5	1.230	2.467	0.099	1.112	24
Maple..........	None............	4.0	0.550*	3.787	0.151	0.330	33
Maple..........	Rueping........	15.0	1.090	2.337	0.093	1.017	13
Birch..........	None............	4.0	0.550*	3.787	0.151	0.330	34
Birch..........	Rueping........	15.0	1.090	2.337	0.093	1.017	14
Catalpa........	None............	20.0	0.880	1.619	0.065	1.243	1
Redwood.......	None............	10.0	1.130	3.135	0.126	0.742	29
Elm............	Rueping........	15.0	1.090	2.337	0.093	1.017	15
Fir.............	None............	7.0	0.900	3.097	0.124	0.549	28
Fir.............	Zinc chloride....	15.0	1.110	2.382	0.095	1.017	19

*Tie-plates not used on these ties.
NOTE—Tie-plates assumed to cost 14 cents each.

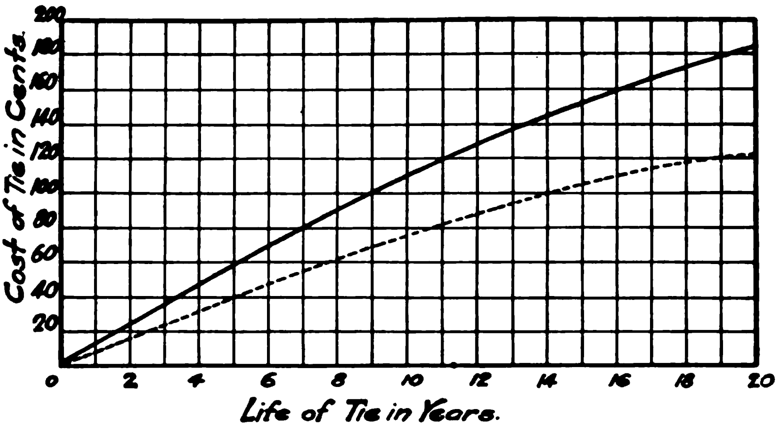


DIAGRAM OF EQUIVALENT COST OF TIES OF DIFFERENT LENGTH OF LIFE.

The dotted curve shows the cost on the basis of a white oak tie costing 68 cents and lasting 9 years; interest at 4 per cent. The solid curve shows the cost on the basis of a tie which costs $1.00 in the track and lasts 9 years; interest at 4 per cent.

"Table 2 shows the same data as in Table 1, except that in the comparison of the ties on the basis of capitalization and annual cost it was considered necessary to use tie-plates on all ties excepting the white

oak, other oaks, chestnut, gum, beech, birch, and maple, which are untreated. In the case of these ties it was considered that they would resist mechanical wear as long as they could resist decay.

"The figures in the last column of this table also represent the ties in their order of merit, as shown by their capitalization and annual cost. By comparing these figures with those in the last column of Table 1 we see the effect upon the capitalization and annual cost of the tie, caused by the use of tie-plates. In Table 1, the white oak tie is No. 25 in order of merit, while in Table 2 it jumps to No. 7. Again, the untreated pine tie drops from No. 29 in Table 1 to No. 31 in Table 2, while the chestnut jumps from No. 24 to No. 3. These figures show also the relative merit of ties of the same kind which are treated with different treatments. For example, in Table 1 the creosoted pine tie holds third place, the pine tie treated with zinc chloride holds the twenty-eighth and the untreated pine tie holds the twenty-ninth place. In case of the creosoted gum tie we find it occupies fourth place, the same tie treated with Rueping process drops to the seventh place, while the untreated gum falls to the thirty-first place."

COMPARISONS OF COST AND LIFE OF TREATED AND UNTREATED TIES.

The tabulated results of 90 answers from members of this Association representing 230,000 miles of railway in the United States, Canada and Mexico to inquiries from your Committee as to the comparative cost and life of treated and untreated cross-ties, indicate that the average life of untreated ties is 7.78 years; average cost, $0.761; the average life of treated ties is 13.85 years; average cost, $1.031.

Information has also been obtained indicating that the average cost of removing an old tie and installing a new tie is about $0.23.

There is, as before mentioned in this report, an undetermined factor of cost incidental to tie changing due to the disturbance of ballast, and consequently of the surface of the track. Whatever this cost may prove to be, it is in inverse ratio to the life of the tie, and therefore least in the tie of longest life. That this cost is considerable and deserving of investigation there seems no doubt, and further consideration will be given it.

So far as your Committee's investigation has proceeded, the comparison of the cost in labor and material of the use of treated and untreated ties favors the tie which is treated with a preservative of such quantity and quality as to preserve the wood fiber against decay to the limit of mechanical wear.

Among considerations favoring the use of treated ties may be mentioned: the rapid and alarming disappearance of the available supply of timbers suitable for use as untreated ties; the possibility of using available supplies of cheaper and so-called inferior timbers when chemically treated; the decrease in cost over a term of years of total tie renewals, owing to the reduced number of necessary tie renewals, and of reduced cost of the labor of surfacing, tamping and replacing of ties, fastenings and ballast resulting therefrom.

The growing realization of the desirability of adzing and boring ties before treating and of obtaining more perfect drainage by boring spike holes clear through the tie will tend to further increase tie life.

It is believed to be feasible, with the formulas and facts here presented, for any intending user of cross-ties to calculate the comparative cost of treated and untreated ties in any particular case; for instance: Knowing the life and cost of an untreated tie and the estimated life of a treated tie which the investigator contemplates using if an ultimate economy will result; the cost of the treated tie may be ascertained. Also, given the life and cost of the untreated tie and the cost of the treated tie, the necessary economical life of the latter may be calculated. Similar calculations are possible for comparisons of cost and life of ties of any materials.

(4) THE USE OF METAL, COMPOSITE AND CONCRETE TIES.

As your Committee has stated before, it is building up a history of cross-ties that will be good for reference to future generations and making reports only on those ties that have been put in the track and used by some steam or electric railroad.

Atchison, Topeka & Santa Fe Railway:

R. J. Parker, General Superintendent, has furnished the Committee the following information in regard to substitute ties on their line:

Baird Railway Steel Tie.—Three of these ties were installed in yard at Newton, Kan., on main track under heavy passenger and freight service, rock ballast, ties 20 in. center to center. No detail plan of this tie is available, but a sketch of the tie is shown in Fig. 1.

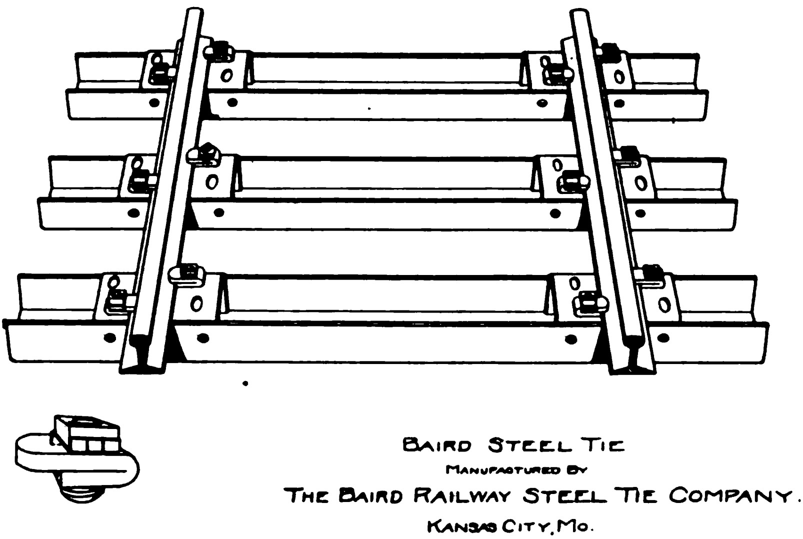


Fig. 1.

Carnegie Steel Tie.—One set No. 8 switch-ties installed in main track, Newton, Kan., April 22, 1913. Rock ballast, heavy passenger and

Fig. 2—Universal Metallic Tie, A., T. & S. F. Ry., Chicago.

Fig. 3—Universal Metallic Tie, A., T. & S. F. Ry., Chicago.

freight service; also one set No. 10 switch-ties at Chanute, Kan., April 22, 1913, main track, rock and gravel ballast, heavy passenger and freight service. The set of ties at Chanute have held line and surface since installed without any labor whatever. The set at Newton were recently destroyed by a derailment and removed from the track.

UNIVERSAL METALLIC TIE (for design see Vol. 13, page 356).—This company installed 83 Universal ties in main track, March, 1913, near Chicago, Ill. The ties were placed in rock and gravel ballast under 85-lb. rail, spaced 20 in. center to center, heavy passenger and freight service. (Figs. 2 and 3.)

One hundred and six Universal ties were put in main track, April, 1913, in front of Florence, Kan., depot. The ties were placed in rock ballast under 85-lb. rail, spaced 20 in. center to center, heavy passenger and freight service.

The ties at Florence were first put in on single track, on a two-degree curve, one per cent. grade, 12 in. stone ballast, this curve being at the foot of a grade and traffic very fast in both directions. The wave motion of the rail together with the vibration caused ballast to move out of the channels and keep the shoulder loose, at the same time this wave motion and vibration did not seem to affect the alinement or surface or riding, but it did pound the ballast into the roadbed more than with wood ties and then after the ballast was all worn smooth, we had trouble maintaining alinement. The ties were taken out and placed in the eastbound main track in front of the passenger station at Florence, Kan., where the wave motion and vibration would not affect the ballast nor move it around as in the place they were first inserted. This was done last April; track very carefully surfaced and tamped and they have not been disturbed since, in fact we have no record of any work having been done on this track since that time.

Baltimore & Ohio Railroad:

JENNINGS COMBINATION RAILROAD TIE.—E. D. Jackson, Division Engineer: "On January 27, 1906, five of these ties were placed in the eastbound main track just west of Ridley Street, Baltimore, Md. The ties were removed from the track on August 8, 1908, and were not used again." (See Fig. 4 for a design of this tie.) The officers on the division on which this test was made advise that they do not consider the construction of this tie would fulfill the requirements of ties in main track or other frequently-used tracks. It is thought that they would buckle in the center if laid on curves. It is also their judgment that these ties could not be satisfactorily insulated.

For the information of the Association, the following, in regard to the Jennings tie, is given. On February 4, 1913, House Joint Resolution No. 393 was introduced by Representative W. J. Brown, Jr., of West Virginia. This resolution directed the Interstate Commerce Commission to investigate and report on the use of the Jennings Combination Railroad Tie upon railroads engaged in interstate commerce. For this purpose the resolution provided that the Commission be authorized to employ persons who are familiar with the subject, and use such of its own employes as are necessary to make a thorough investigation. In making this investigation the Commission may make a practical test of said appliance upon some railroad in the United States.

The resolution further provided that the Commission may at its discretion tabulate accidents upon railroads engaged in interstate commerce

resulting from a spread of track, broken rail, and defective roadbed for the period covering the last five years and to report to Congress the number of persons killed or injured and the damage to property by reason of defects herein above mentioned, etc.

In addition to directing the Commission to recommend legislation and empowering them to issue subpœnas, administer oaths, etc., the legislation carried with it an appropriation of $25,000. On February 4,

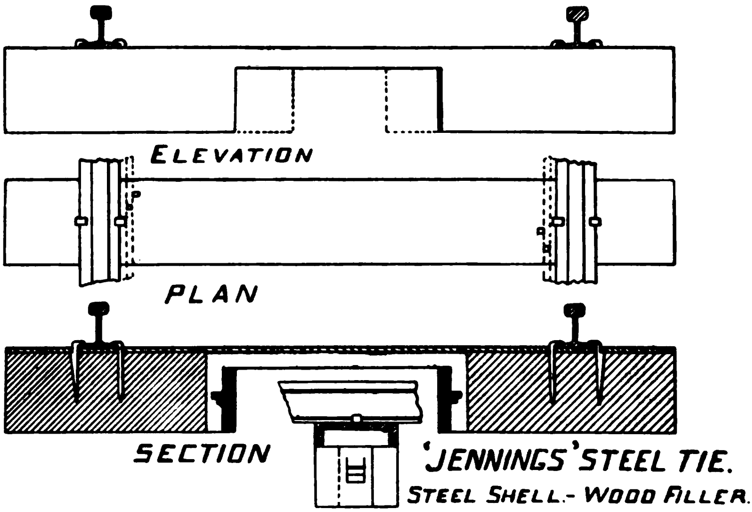


FIG. 4.

1913, this resolution was referred to the Committee on Interstate and Foreign Commerce. The resolution is still with this committee.

Bessemer & Lake Erie Railroad:

During the year 1913, this company has received 64,438 steel ties, and 92,300 ties are still due on their 1913 order; in addition to this, 3,200 ties of the same design as were installed by the Carnegie Steel Co., at Atglen, Pa., on the Pennsylvania Railroad (see Fig. 9), have been received but have not yet been put in the track. This company will continue to use the steel tie almost exclusively on its main tracks from North Bessemer to Conneaut Harbor.

Buffalo Creek Railroad:

S. M. Kielland, Engineer, reports that all of the 32 Corell ties in their tracks have been removed during the past year. (See Vol. 14, page 743.)

Buffalo, Rochester & Pittsburg Railway:

E. F. Robinson, Chief Engineer: "No further information. Carnegie ties at Colden, N. Y., are still in and giving satisfactory service."

Chicago & Alton Railroad:

H. T. Douglas, Jr., Chief Engineer, advises that the 63 Simplex ties, manufactured by the Chicago Steel Railway Tie Co., are still in the track and are giving the highest degree of satisfaction. (See Vol. 14, page 745.)

Mr. Douglas further states that all of the Kimball ties which were in their track at Lockport, Ill., have been removed. These ties were put in in October, 1905.

Chicago, Burlington & Quincy Railroad:

Geo. H. Bremner, Engineer, Illinois District, gives the following information: Universal Steel Ties (for design see Vol. 13, page 356). "In March, 1911, this company installed 100 ties manufactured by the Universal Metallic Tie Co., Salt Lake City, in a running track at Chicago. The ties were spaced 21-in. centers, gravel ballast, traffic—light freight. Oak ties were used at the joints, as no steel ties were furnished for this purpose. These ties are satisfactory and show no signs of wear. They are corroding slightly, about 1½ in. below the top of the tie."

Cleveland, Cincinnati, Chicago & St. Louis Railway:

C. A. Paquette, Chief Engineer, Engineer Maintenance of Way, says they have put in no additional substitute ties. The one mile of Carnegie steel ties in westbound main track between Newpoint and Greensburg, Ind., are still in and giving excellent service.

Cornwall & Lebanon Railroad:

SNYDER STEEL TIE (for design see Vol. 13, page 352).—Two hundred of these ties were put in southbound main track near Mt. Gretna about 1907. A. D. Smith, President and General Superintendent, advises they are still in the track and there has been very little change since last year's report.

Duluth & Iron Range Railroad:

Two thousand Carnegie steel ties were put in their main track in 1905. These are still in the track and giving satisfactory service.

Duluth, Missabe & Northern Railway:

This road put in 22,400 Carnegie steel ties in the fall of 1908 and spring of 909. Two miles were placed between Duluth and Proctor on double track, one mile in each track, the remainder being placed about 50 miles north of Duluth on double track, 1½ miles on each track. These ties are giving excellent service.

Elgin, Joliet & Eastern Railway:

BATES CONCRETE TIE (for design see Vol 14, page 750).—Sixty-two ties were installed in eastbound main track at Whiting, Ind., May 1, 1912.

A. Montzheimer says, "The Bates Concrete Ties are holding up in good shape and as far as I can see are in as good condition as when first installed." In regard to the insulation of this tie, F. B. Wiegand, Signal Engineer, Lake Shore & Michigan Southern Railway, advises, December 4th, as follows:

"I made personal test of this tie on June 30th and at that time we reported that we could not say whether or not the ties would be satisfactory where track circuits are in operation, although we knew there would be more leakage than where wooden ties were used, and the length of track section for the same battery would therefore be less with the reinforced concrete tie than with the wooden tie.

"Complete information could not be had at that time on account of steel ties being in service adjacent to the concrete ties and the section of track with the concrete ties not being insulated from the adjoining section.

"After this test, Mr. Bates wished to have this section insulated and a further test was made, after which we reported as follows:

"We had further test made but we could only determine with the number of ties in service that the leakage would be materially higher than with wooden ties and if ties are installed for test, we will without doubt have to provide short track sections.

"On account of the leakage, Mr. Bates suggested enameling the anchor plates. The following quotation is taken from his letter of July 15th:

"'Mr. Buchanan will no doubt report to you many interesting discoveries in this test, among them is one of most vital interest to myself and that is the small leakage of current shown is due to the anchor plate imbedded in the concrete for holding the rail; this seems to absorb the current from the rail and distributes it through the concrete to the reinforcements; it is so slight, however, that if the anchor plate were enameled this would provide sufficient non-conducting material to stop this leakage. This discovery alone is certainly worth the time and energy in the tests we have made. There is no doubt in my mind now that if this tie stands the endurance of high speed (and I am sure it will) we are in a fair way of having the railway tie problem solved.'

"In replying to this I wrote Mr. Bates the following:

"'The tests showed that the leakage between rails would be materially increased by replacing wooden ties with your ties and it will therefore be necessary to reduce the length of track section.

"'Enameling of the plates spoken of in your letter would certainly not prove satisfactory for any length of time on account of the wear due to the pressure of the ends of the hook bolts on the plates.'"

Carnegie Steel Ties.—During the past year this road put in 556 sets of Carnegie steel switch-ties, making 710 sets in to date and further they have in 12,150 Carnegie steel cross-ties, the first of which were put in in 1907. These ties are giving satisfactory service.

Florida East Coast Railway:

This road intsalled 16 Percival concrete ties at St. Augustine, Fla., March, 1906, in their main track. These ties are giving good service.

Galveston, Harrisburg & San Antonio Railway:

D. K. Colburn, Assistant General Manager, furnishes the following information:

Percival Concrete Ties (Vol. 11, page 894).—Ties at Edgewater, Texas:

Test No. 1—50 ties installed in main track interspersed with ordinary cypress ties, gravel ballast. These ties installed October 22, 1906. On February 9, 1907, a wreck broke three ties, which were removed; at the same time 14 other ties were badly disfigured. On January 28, 1908, it

developed that 6 ties in addition to the 14 damaged by wreck had developed cracks, at which date 20 ties were renewed. Inspection of June, 1909, showed 4 ties were broken at or near the rail and 3 developed slight cracks near the center.

The July, 1911, report showed 2 more ties were broken and balance developing cracks, and report of July, 1912, showed 3 more ties broken. The report of July, 1913, shows 9 ties removed between January 1 1913, and July 1, 1913.

Test No. 2—50 ties installed in main track, ties laid out of face, gravel ballast. These ties were installed October 22, 1906. All reports show these ties in good condition up to July, 1912, at which date one tie was reported broken. The reports of July, 1913, shows the broken tie as having been removed.

Test at Bayou Sale, La.—Fifty ties installed in main track, laid out of face. These ties were installed January 20, 1910. To date there have been no failures reported.

Hocking Valley Railway:

Sixteen ties manufactured by the International Steel Tie Co., Cleveland, Ohio, were placed in northbound freight track, Columbus, Ohio, in 1911. Wm. Michel, Chief Engineer, says their ties are still in and they expect to install a few more this year.

Lake Terminal Railroad (Lorain Steel Co.):

F. W. Waterman, Engineer, advises that he is using steel ties exclusively for replacements and new work. During 1912 he used 23,000 Carnegie steel ties, M-21 section. (Figs. 5 and 6.)

Monongahela Connecting Railroad:

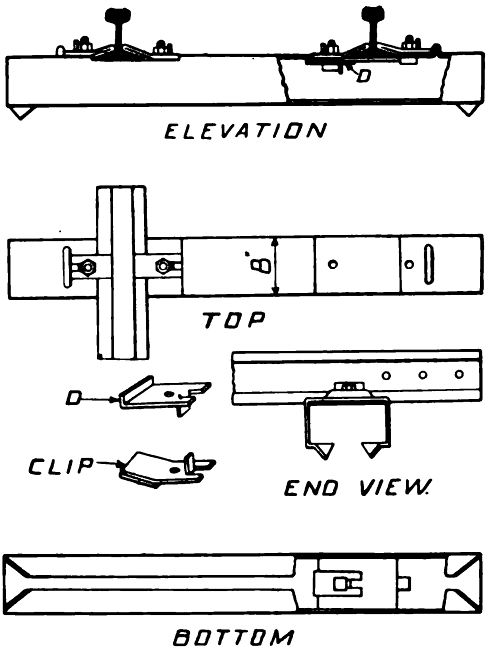
McCune Steel Tie.—This tie is the invention of Frank McCune, General Manager, Monongahela Connecting Railroad. For design see Fig. 7, and for photograph of ties in track see Fig. 8.

In the fall of 1905, Mr. McCune had 45 ties made of 3/16-in. plate and placed in their tracks at Pittsburgh, Pa. The ties were part on tangent and part on a 16-degree curve, grade 1 per cent., traffic extremely heavy, over 100 trains and engines passing over them each day. These ties were spaced 15 to a 30-ft. rail. As stated above they were made of 3/16-in. plate and were made by hand. Mr. McCune would have used heavier material, but this was the limit they could work without special machinery. Mr. McCune further states that the ties put in in 1905 were defective before they were placed in the track, made so by constant heating and bending in order to get them to shape because he had no machinery to work with.

These ties were removed from the track at the end of two years, but Mr. McCune says the test demonstrated that a tie of this design made of material of sufficient thickness, say 5/16-in., would hold up under almost any pressure. Such a tie would weigh 190 lbs. and is the tie given in Fig. 8.

FIG. 5—CARNEGIE STEEL SWITCH TIES, LAKE TERMINAL RAILROAD, LORAIN, OHIO.

FIG. 6—CARNEGIE STEEL TIES, LAKE TERMINAL RAILROAD, LORAIN, OHIO.



McCUNE STEEL TIE.
FIG. 7.

FIG. 8—McCUNE STEEL TIE, MONONGAHELA CONNECTING RAILROAD, PITTSBURGH, PA.

Mr. McCune expects to have some ties of this heavier design made and put in their track early next year, which ties it is proposed to press cold, thus preserving the life of the steel to a greater extent.

New York Central & Hudson River Railroad:

UNIVERSAL METALLIC TIE (for design see Vol. 13, page 356).—On February 10, 1911, this company installed 99 Universal ties, manufactured by the Universal Metallic Tie Co., Salt Lake City. The ties are in main track under 100-lb. rail, spaced 18 to a rail, length (33 ft.) in stone ballast, traffic heavy freight and express.

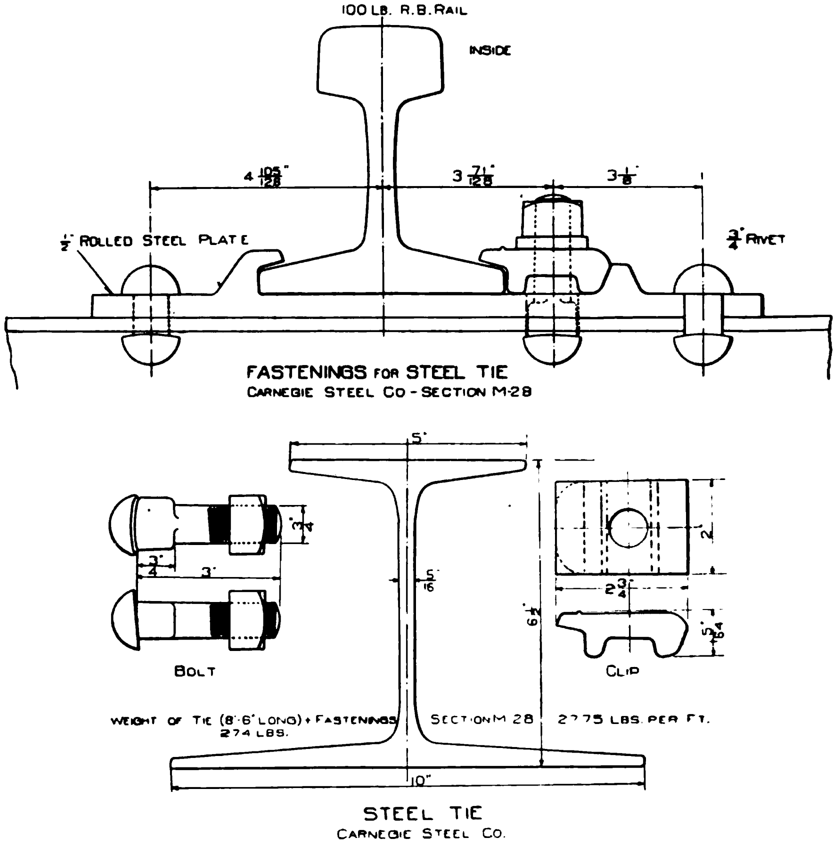


FIG. 9.

The ties are insulated, insulation renewed October 29, 1912. The blocks under the rail have never been renewed, but are decaying very fast. G. W. Vaughan, Engineer Maintenance of Way, says the ties do not hold well in the ballast and it is expensive to renew rail on them. He states that the ties do not seem to have been affected as yet by salt drippings from refrigerator cars.

Pennsylvania Railroad:

CARNEGIE STEEL TIES.—This company has installed, December 1, 1913, 3,000 Carnegie steel ties of heavy design near Atglen, Pa., on their low-grade freight line, eastbound main track. The ties are not insulated, but the Carnegie Steel Company advise that they can be furnished with insulation, a piece of fiber being placed under the plate, much the same as is shown in the design of their M-21 tie. (For design of this heavier tie see Fig. 9.)

These ties are placed in three sections of about 1,000 ties in each section, spaced 18, 19 and 20 ties to a 33-ft. rail. Part are in cinder ballast and part are in stone ballast. Your Sub-Committee inspected these ties. In addition to the above they laid 8 sets of No. 8 turnouts in Pitcairn, Pa., yard, two years ago and they have been giving satisfactory service. Eight more sets have been ordered.

MECHLING AND SMITH STEEL TIE.—One hundred of these ties placed in a running track in Brushton Yard (date installed not given). These ties still in the track and giving satisfactory service.

MORGAN STEEL TIE.—This tie is manufactured by the Morgan Engineering Co., Alliance, Ohio, and a test of same is being made at Atglen, Pa. The ties are made from old rail by special machinery and a stretch 400 ft. long was laid about two years ago. A cross-section of this tie is shown in Fig. 10, and a plan showing the general arrangement of the ties in the track is shown in Fig. 11. No definite conclusion has been reached as to their economy.

SNYDER STEEL TIE (for design see Vol. 13, page 352).—1,600 at Derry Pa., and 966 at Conemaugh, Pa. These ties are still in the track and there has been no change since our last report.

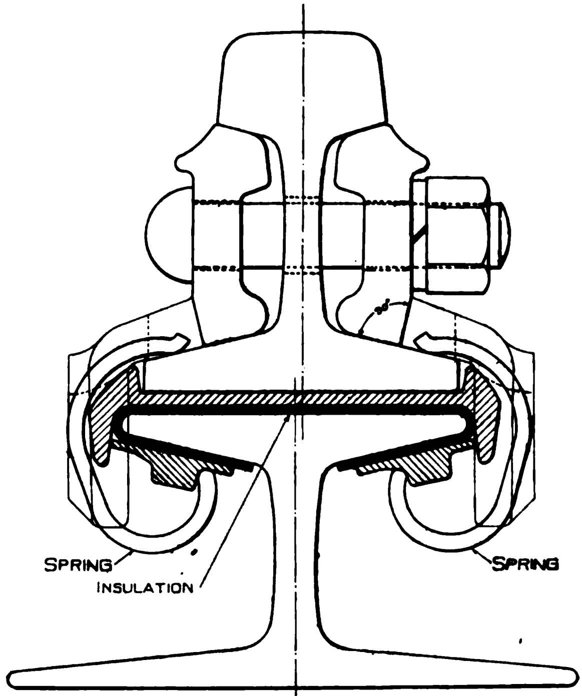
Pennsylvania Lines (Northwest System):

CHAMPION COMBINATION CONCRETE AND STEEL TIE.—This tie is manufactured by the Champion Steel Railway Tie Co., Pittsburgh, Pa. (For design see Fig. 12 and photographs of the tie in the track are given in Figs. 13, 14 and 15.)

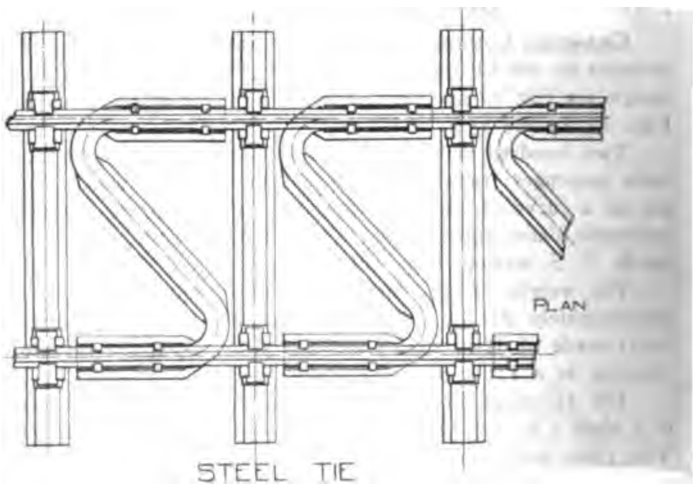
Two hundred and three of these ties were placed in the westbound main passenger track December 1, 1913, near Emsworth, Pa. The ties are on a curve of about 1 degree 30 min. They are insulated, being in automatic limits and are placed out of face—spaced 19 to a 33-ft. rail—100-lb. P. S. section, rock ballast.

The weight of the steel in this tie is 140 lbs., weight of concrete approximately 460 lbs., total weight 600 lbs. As shown on the plan, the tie is made of ¼-in steel plate, and J. A. Hyle, the inventor, says the concrete is a 1:3:5 mix.

The fastening on this tie is of special interest. On top of the tie is a plate 7 by 10½ in. for intermediates and 7 by 13 in. for joint ties. This plate may be rolled, but on the Emsworth ties it is made of cast steel. The projections on this plate are so formed that they hold the rail



STEEL TIE
MORGAN ENGINEERING CO.,
ALLIANCE, O.
FIG. 10.



STEEL TIE
MORGAN ENGINEERING CO.,
ALLIANCE, O.
FIG. 11.

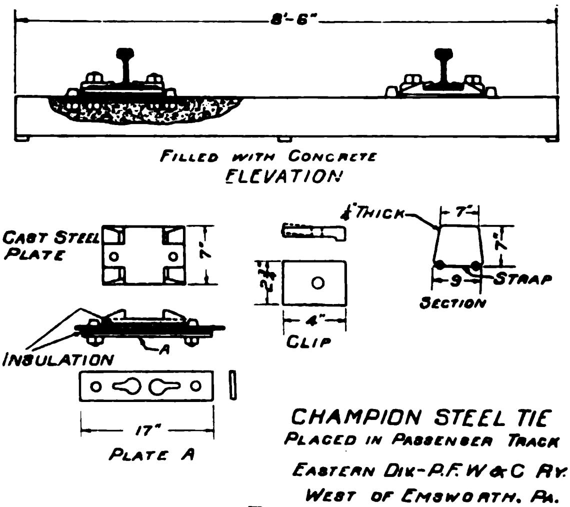


FIG. 12.

FIG. 13—CHAMPION STEEL TIE, PENNSYLVANIA LINES, EMSWORTH, PA.

FIG. 14—HYLE STEEL-CONCRETE TIE, PENNSYLVANIA LINES, EMSWORTH, PA.

FIG. 15—CHAMPION STEEL TIE, PENNSYLVANIA LINES, EMSWORTH, PA.

clip at all times square with the tie, a very important feature. This plate is insulated from the tie by a number of thicknesses of insulating paper or fiber which the inventor thinks will act as a cushion in addition to providing for the track circuits, the bolts are insulated where necessary with thimbles or washers and the plate on the under side of the tie is insulated with fiber or insulating felt.

It will be noticed that the bolts holding the plate under the top table of the tie have the nut in a pocket in the concrete which permits the bolt to be tightened from the top.

As noted above, a special plate is used at the joint. No special angle bars are required and no change is made in the tie proper at the joints. A member of the Sub-Committee inspected these ties in the track December 9, 1913, and he reports that this test is being watched with a great deal of interest.

Fig. 16—Reigler Concrete-Steel Tie, Pennsylvania Lines, Emsworth, Pa.

Reigler Combined Steel and Concrete Tie (see Vol. 11, page 893 for design).—Fifteen of these ties were put in westbound main passenger track, May, 1908, at Emsworth, Pa., where they are subject to very heavy traffic. They are still in the track and giving satisfactory service with no apparent depreciation. Fig 16 is a photograph of these ties after 5½ years' service. L. J. Reigler, Engineer, Pennsylvania Lines, the inventor of this tie, believes they have still a long life ahead of them and it is of interest to note that these ties are approaching the average life of wood ties used under similar service.

Rohm Steel Tie (for design see Vol. 13, page 355).—Twelve of these ties put in eastbound freight track June, 1910, Sewickley, Pa., are still in the track.

Universal Steel Tie (for design see Vol. 13, page 356).—Ninety-eight of these ties were installed in eastbound main freight track near Emsworth, Pa., December, 1910. They were all removed September 6, 1913, a number being broken under the rail seat. The ties were not satisfactory.

On June 15, 1914, the Universal Metallic Tie Co. advised your Sub-Committee that they had a report from the Pennsylvania Lines saying that during the time these ties were in there was not any material difference in the line and surface of the steel-tie track and the adjoining stretch of wood-tie track, and that the insulation did not give any trouble. The appearance of the ties after they were removed from the track indicates that they were too weak for the loads imposed. About 90 per cent. of the ties developed cracks at the rail seat where the metal had been punched upward to provide means for the rail fastening, and further the bottom of the ties was considerably corroded.

Commenting on the report of the Pennsylvania Lines, B. S. Rupp, Contracting Manager of the Universal Metallic Tie Co., says: "You will notice that the ties are bent on the end, showing plainly, as we have always contended, the ballasting had been done almost entirely on the end of the tie. Had the tie been ballasted the same distance in from the rail as it was out, the tie would not have bent up on the ends. I reported this matter a number of times to the Section Foreman, as I could plainly see the ballast was driven in from the end of the tie, and not under the rail, and distributed on each side of the rail, as it should have been. The ties were put in the ground without any treatment, and as the place where they were installed was rather low, the ballast was nearly always wet and soft, consequently there would be some corrosion. I had an experienced chemist and engineer look over the ties, make a careful examination of the place they were installed, and they both decided that some chemical action had taken place in the metal while the ties were in the track or the metal had been burned while in the course of construction."

Mr. Rupp concludes, "While perhaps there may be something in the statement that the ties were made of too light material for the heavy traffic of this road, we do not feel that this alone was responsible for the condition of the ties when they were removed. There are a number or roads that are now using our ties, which have as heavy equipment as the Pennsylvania Lines, and while perhaps they are not running as many trains, the ties have been in fully as long as on the Pennsylvania and are yet in perfect condition."

The Sub-Committee wishes to call attention to the reports of other roads in regard to this tie and suggests that they be considered carefully in connection with the above. These reports will be found under the following roads: A. T. & S. F., C. B. & Q., N. Y. C. & H. R. R., and P. & L. E. R. R.

Pennsylvania Lines (Southwest System):

Kimball Concrete Tie (For design see Vol. 14, page 760).—One tie was installed in a slow-speed running track in Scully Yard, November 21, 1911. This tie had prior to this been in the main track of the Pere Marquette Railroad near Saginaw, Mich., having been put in in 1902 and taken out and sent to Mr. Cushing for test in 1911.

Mr. Cushing states that this tie is still in the track and in good condition.

Pittsburgh & Lake Erie Railroad:

Atwood Concrete Steel Tie (for design see Vol. 12, page 379).—J. A. Atwood, Chief Engineer, says the five ties of this design are still in the track and that they are having 12 of these ties made on slightly different lines and with a different rail fastening which were to be placed in the track as soon as complete. No details of this revised tie were furnished, but will try to get same for the next report.

Mr. Atwood says that the ties in the track have given first-class service without expense, since being installed October 10, 1908.

Brukner Reinforced Concrete Tie (for photographs of this tie see Vol. 13, page 358 and Vol. 14, page 761).—The Sub-Committee has no report in regard to these ties since last year.

Carnegie Steel Ties, with wedge fastening (for design see Vol. 12, page 375).—Six of these ties were placed in the track near the Terminal Station, May, 1908. The Sub-Committee has no report on these ties this year.

With bolt and clip fastening.—Three thousand of these ties laid August, 1907, in westward freight track, McKees Rocks. The Sub-Committee has no additional information on these ties. They are still in the track.

International Steel Tie (for design and photographs see Vol. 12, pp. 361-363).—Twenty-four of these ties were put in the track at Glassport, Pa. The Sub-Committee has no report on these ties this year.

Maxey Steel Tie.—This tie is manufactured by the United States Steel Tie Co., Pittsburgh, Pa. No detail plans of this tie are available, but photographs of same are shown in Figs. 17, 18 and 19.

Mr. Atwood says on Oct. 10, 1912, they installed 10 of these ties in their westbound main track at Glassport, Pa., for experimental purposes. He adds: "They have given good service during the 14½ months they have been in the track."

Universal Steel Tie (for design see Vol, 13, page 356).—One hundred of these ties were placed in northbound main track near the Terminal Station, Pittsburgh, Pa., February, 1911. The Sub-Committee has no report on these ties this year.

Pittsburg, Shawmut & Northern Railway:

Seven hundred and ninety-five Carnegie ties installed in 1907. H. S. Wilgus, Engineer Maintenance of Way, states they have nothing further to advise in regard to these ties. They are still in the track.

Fig. 17—Maxey Steel Tie, Pittsburgh & Lake Erie Railroad.

Fig. 18—Maxey Steel Tie, Pittsburgh & Lake Erie Railroad.

Fig. 19—Maxey Steel Tie, Pittsburgh & Lake Erie Railroad.

Union Railroad (Pittsburg, Pa.):

F. R. McFeaters, Superintendent, says they have, during the past year, put in 46,654 steel cross-ties and 156 sets of steel switch-ties manufactured by the Carnegie Steel Co.

Union Pacific Railroad:

Shane Steel Tie (for design see Fig. 20).—This tie is manufactured by the Steel Railway Tie & Appliance Co., Denver, Colo. A. F. Vick Roy, Superintendent, advises they placed 33 of these ties in their main track at Denver, October 23, 1912. The ties are under 90-lb. rail, spaced 22

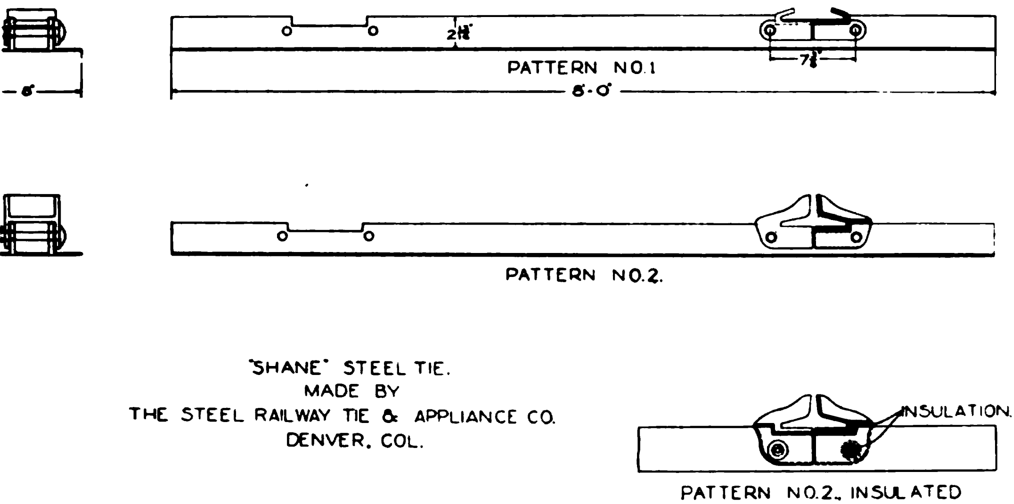


Fig. 20.

in. center to center, cinder ballast, heavy traffic. The ties have been very satisfactory so far, but Mr. Vick Roy says in case of a broken rail it is a very slow process to change out, account necessary to remove all fasteners before rail can be removed.

Appendix A.

COMPARATIVE HOLDING POWER OF DIFFERENT POINTED GOLDIE AND CUT SPIKES.

By H. B. MacFarland, Engineer Tests, Atchison, Topeka & Santa Fe Railway System.

Object.—The object of this test was to determine the holding power of different pointed Goldie and chisel-pointed cut spikes and the tearing effect on the fiber due to driving the spike into the wood.

A particular object was to determine what taper of Goldie spike was most advantageous.

The data were also obtained to determine if the Goldie spike should not be adopted as standard instead of the chisel-pointed cut spike.

The general dimensions, and other detailed information in regard to the spikes, are shown below:

No.	Point.	Point Length Inches.	End Inches.	Spike Length Inches.	Weight Grams.	Size of Spike Inches.
1	Chisel	1.1	0.05 by 0.55	5.80	260	0.57 by 0.56
2	Chisel	1.1	0.05 by 0.55	5.75	260	0.57 by 0.57
3	Sharp	1.1	0.06 Square	5.70	250	0.57 by 0.57
4	Sharp	1.0	0.07 Square	5.75	251	0.57 by 0.56
5	Blunt	0.5	0.25 Square	5.35	255	0.58 by 0.56
6	Blunt	0.5	0.25 Square	5.30	252	0.58 by 0.56
7	Blunt	0.8	0.25 Square	5.60	254	0.58 by 0.57
8	Blunt	0.8	0.25 Square	5.40	251	0.57 by 0.57
9	Blunt	1.25	0.25 Square	5.35	249	0.57 by 0.58
10	Blunt	1.15	0.25 Square	5.45	249	0.58 by 0.57
11	Blunt	1.70	0.25 Square	5.30	224	0.57 by 0.57
12	Blunt	1.60	0.25 Square	5.45	242	0.57 by 0.57

Three pieces of 6 by 6 in. by 3½ ft., hard pine dimension lumber untreated were secured for test. Three ties, one 6¼ by 8½ in. by 8 ft. hewn hard pine, treated; one 6¼ by 8½ in. by 8 ft. hewn red oak; treated; and one 6⅝ by 8¾ in. by 8½ ft. hewn white oak, untreated, were secured from Roadmaster Hansen to be used in this test.

At the conclusion of tests on the above specimens, six additional ties, two each of the above mentioned woods, were secured for further tests.

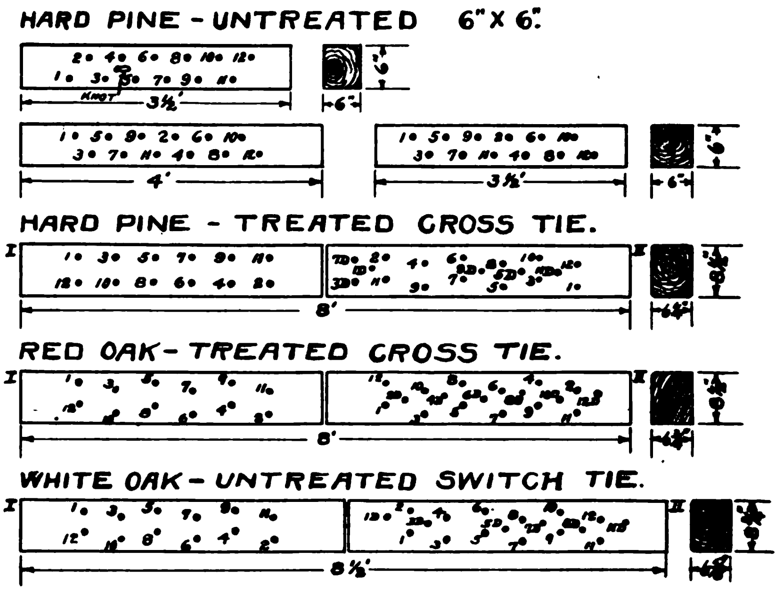
The following photograph shows only one of each series of points tested, the numbers under each one indicating the series to which they belong.

Tests.—This test was made to determine only the relative holding power of the different-shaped spikes in the same wood; therefore, it was considered sufficient to make the determinations using the standard ⅜-in. hole 4 in. deep. This was followed out with a few exceptions. In case of the hard pine untreated dimension lumber a 2½-in. hole was

1 and 2. 3 and 4. 5 and 6. 7 and 8. 9 and 10. 11 and 12.

Photograph showing six different points used in this test. No. 1 is the chisel point now commonly used; the other five were specially designed for this test.

SPIKE HOLDING TEST.



SPIKES

KIND.	NO.	POINT LENGTH	POINT SIZE	NO.	POINT LENGTH	POINT SIZE.
CHISEL	1	1.1"	.05"X .55"	2	1.1"	.05"X.55"
SHARP	3	1.1"	.06" SQ.	4	1.0"	.07" SQ.
BLUNT	5	0.5"	.25" "	6	0.5"	.25" "
"	7	0.8"	.25" "	8	0.8"	.25" "
"	9	1.25"	.25" "	10	1.15"	.25" "
"	11	1.70"	.25" "	12	1.60"	.25" "

used in a few instances. In one series of special tests on the ties, the spikes were driven without holes.

The spikes were marked at a point 4⅛ in. from the end, as seen in the preceding photograph, and driven to this line, thus each spike was driven into the wood the same distance.

The spikes were spaced as shown in the preceding diagram, being staggered so as to split the wood as little as possible. The points marked 1D, 3D, etc., show the spikes driven without holes, all the others having been bored ⅜-in. to a depth of 4 in. with the exceptions shown in data.

The spikes were pulled in the 100,000-lb. Riehle testing machine.

After pulling the spikes, the ties were sawed and split through the spike hole so as to note the effect of the spike on the fiber. Photographs were taken of these splits and are shown on pp. 776-789 inclusive.

The holding power of the spikes as determined by the several tests was as follows:

HARD PINE BLOCKS—UNTREATED.

No.	—Load in Pounds— 1st Block.	2d Block.	3d Block.
1	3,000	3,800	4,000
2	2,880	3,450	4,100
3	4,100	3,360	3,520
4	2,840	3,300	3,900
5	3,170	4,000	3,660
6	2,900	3,350	4,130
7	2,620	3,400	3,600
8	2,700	3,970	3,900
9	3,160	3,840	3,540
10	3,090	3,350	4,100
11	3,110	3,640	3,720
12	3,370	3,290	2,730

Note.—1stBlock, all holes 2½ in. deep.
2d Block, odd holes 2½ in. deep; even holes 4 in. deep.
3d Block, odd holes 2½ in. deep; even holes 4 in. deep.

TIES—FIRST SERIES.

⅜ by 4 in. Bored Holes.

Spike No.	Load in Pounds to Start Spike. Hard Pine Treated.	Red Oak Treated. I	Red Oak Treated. II	White Oak.
1	2,840	4,040	3,860	6,380
2	3,590	3,280	3,020	7,100
3	3,180	4,100	3,580	6,720
4	2,950	3,930	3,390	6,340
5	3,330	4,590	4,100	7,430
6	2,810	4,320	3,540	7,200
7	3,080	4,050	4,270	5,690
8	2,360	3,920	4,140	5,670
9	3,130	4,250	4,600	7,100
10	2,100	2,840	4,790	6,590
11	3,450	3,890	4,660	6,130
12	1,920	3,400	4,610	6,440

SPIKES DRIVEN—NO HOLES.

1D	2,770	....	....	4,020
2D	....	3,350	....	....
3D	3,100	....	....	4,280
4D	....	3,250	....	....
5D	2,460	....	....	4,860
6D	....	3,460	....	....
7D	2,760	....	....	5,200
8D	....	3,390	....	....
9D	2,730	....	....	5,680
10D	....	2,820	....	....
11D	2,800	....	....	5,000
12D	....	4,000	....	....

TREATED HARD PINE TIE.

⅜ by 4 in. Bored Holes.

	—Load in Pounds—			
		I		II*
No.	Start.	Pull.	Start.	Pull.
1	2,685	1,755	3,620	2,130
2	3,200	2,100	2,935	1,650
3	3,750	2,150	4,110	2,890
4	3,750	2,650	4,170	2,375
5	3,150	2,575	4,785	3,100
6	3,275	2,505	3,695	2,450
7	3,850	2,925	4,055	3,060
8	3,605	2,575	3,970	2,700
9	3,225	2,400	3,560	2,050
10	3,100	1,850	3,885	4,595
11	3,675	2,000	3,890	2,225
12	3,125	1,600	4,290	2,490

TREATED RED OAK TIE.

⅜ by 4 in. Bored Holes.

	—Load in Pounds—			
		I		II*
No.	Start.	Pull.	Start.	Pull.
1	6,125	4,175	4,970	2,975
2	5,275	3,090	6,000	4,430
3	7,800	4,875	6,655	3,875
4	6,175	3,850	7,465	5,500
5	6,940	4,400	6,875	4,750
6	6,300	3,950	7,615	5,370
7	7,700	4,950	6,650	4,650
8	6,075	3,735	7,500	5,200
9	7,260	4,240	7,230	4,035
10	5,540	3,300	7,675	4,560
11	8,190	3,965	6,945	4,775
12	5,500	3,125	6,805	4,250

*Average for two pulls.

WHITE OAK TIE.

⅜ by 4 in. Bored Holes.

No.	I Start.	I Pull.	II* Start.	II* Pull.
1	5,835	3,750	4,855	2,950
2	5,665	3,250	4,405	2,875
3	6,370	4,525	5,575	3,300
4	5,980	3,625	6,100	3,400
5	6,136	4,250	4,700	3,000
6	5,660	3,450	5,125	3,590
7	5,540	3,670	5,190	3,450
8	5,495	3,535	5,950	4,000
9	5,510	3,120	5,070	3,020
10	5,855	2,920	3,925	2,400
11	5,830	3,135	6,170	3,350
12	6,655	3,465	5,325	3,400

—Load in Pounds—

TREATED HARD PINE TIE.

Spikes Driven—No Holes.

Spike No.	I Start.	I Pull.	II Start.	II Pull.
1	1,800	1,300	2,500	1,750
2	2,000	1,200	2,000	1,100
3	2,500	1,600	3,830	2,450
4	2,500	1,600	2,930	2,220
5	2,100	1,600	3,600	2,650
6	2,660	2,000	2,250	1,800
7	2,200	1,500	3,450	2,700
8	2,200	1,300	2,269	1,500
9	2,400	1,600	2,920	2,250
10	2,150	1,600	2,570	1,500
11	2,100	1,500	4,120	2,400
12	2,150	1,350	2,720	1,700

—Load in Pounds—

TREATED RED OAK TIE.

Spikes Driven—No Holes.

Spike No.	I Start.	I Pull.	II Start.	II Pull.
1	5,300	3,300	4,850	3,150
2	5,220	3,100	5,750	3,420
3	5,050	3,900	6,850	4,600
4	5,300	3,500	6,670	4,800
5	5,700	3,900	5,830	4,500
6	5,700	4,450	5,900	4,000
7	5,580	4,200	6,060	4,400
8	5,670	4,500	5,600	3,950
9	4,670	2,830	5,100	2,800
10	5,200	3,480	4,400	3,000
11	5,560	3,300	6,500	3,200
12	6,610	3,800	5,750	3,000

—Load in Pounds—

*Average for two pulls.

WHITE OAK TIE.

Spikes Driven—No Holes.

Spike No.	I Start.	I Pull.	II Start.	II Pull.
	—Load in Pounds—			
1	3,880	2,500	4,650	2,850
2	3,690	2,870	1,770	1,260
3	3,580	2,200	3,750	2,600
4	2,630	1,200	1,900	1,000
5	3,880	2,200	3,050	2,550
6	2,750	1,600	1,850	1,200
7	3,900	2,350	2,150	1,770
8	2,520	1,900	3,000	2,450
9	3,780	1,760	1,700	1,000
10	2,900	1,550	2,550	1,840
11	3,060	1,500	3,500	1,950
12	3,050	1,500	2,360	1,400

Note.—End of tie badly checked.

AVERAGE HOLDING POWER FOR DIFFERENT WOODS—TIES.

Force to Withdraw—Pounds—3/8 by 4 in. Holes.

Spike.	Hard Pine Treated Start.	Hard Pine Treated Pull.	Red Oak Treated Start.	Red Oak Treated Pull.	White Oak Untreated Start.	White Oak Untreated Pull.
1 & 2	3,140	1,910	4,810	3,670	5,570	3,200
3 & 4	3,770	2,520	5,940	4,525	5,995	3,710
5 & 6	3,590	2,660	5,910	4,590	5,250	3,570
7 & 8	3,630	2,815	6,000	4,640	5,640	3,665
9 & 10	3,310	2,210	5,995	4,090	5,460	2,865
11 & 12	3,100	1,970	5,870	4,015	6,100	3,200
	Force to Withdraw—Pounds—No Holes.					
1 & 2	2,215	1,340	4,900	3,240	3,600	2,370
3 & 4	2,975	1,970	5,430	4,200	3,230	1,750
5 & 6	2,615	2,010	5,320	4,210	3,280	1,890
7 & 8	2,575	1,750	5,260	4,240	3,360	2,120
9 & 10	2,560	1,740	4,440	3,030	3,330	1,560
11 & 12	2,780	1,740	5,690	3,320	3,395	1,590

AVERAGE HOLDING POWER FOR ALL TIES TESTED.

Force to Withdraw—Pounds.

	3/8 by 4 in. Holes Start.	3/8 by 4 in. Holes Pull.	No Holes Start.	No Holes Pull.
1 & 2	4,590	2,920	3,570	2,315
3 & 4	5,300	3,590	3,870	2,640
5 & 6	5,020	3,615	3,740	2,700
7 & 8	5,160	3,700	3,730	2,710
9 & 10	5,010	3,040	3,440	2,090
11 & 12	5,110	3,080	3,950	2,550

Hard Pine, Treated. Size, 6¼ by 8½ in. by 8 ft.

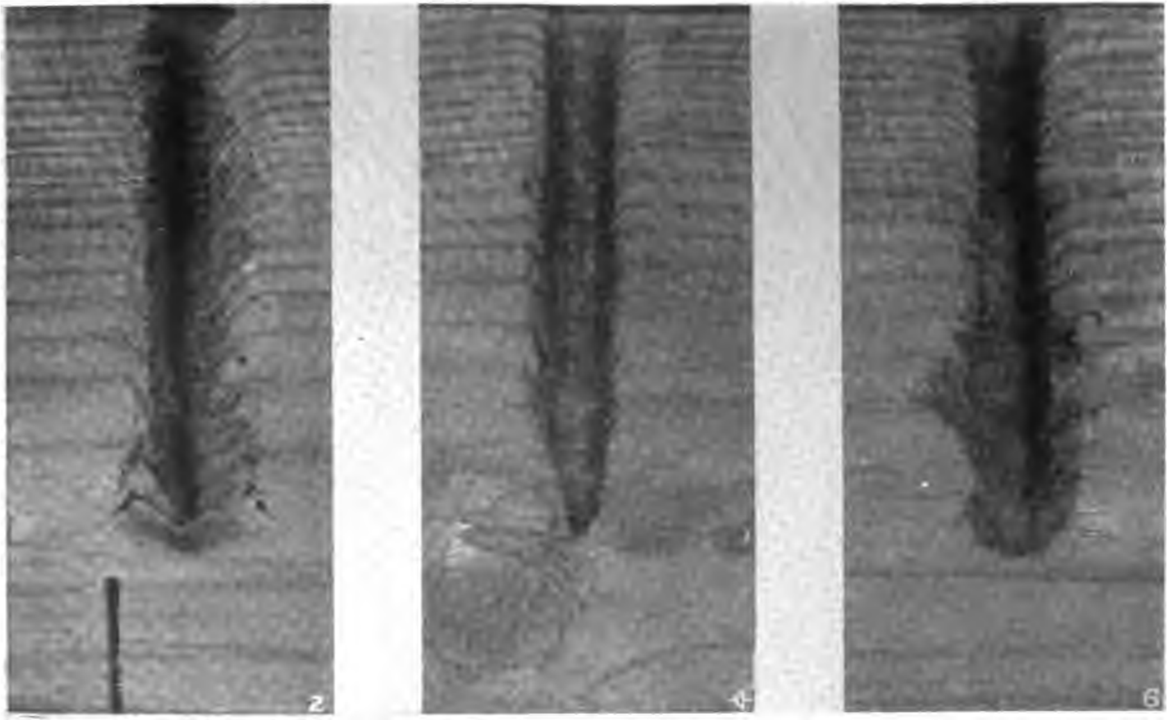
Photograph showing rings and depth of creosote in hard pine treated tie. Cracks are due to driving spike.

Red Oak Tie, Treated. Size, 6¾ by 8½ in. by 8 ft.

Photograph showing rings of red oak treated tie used in test. Note checks in bottom of tie.

White Oak Tie, Untreated. Size, 6⅝ by 8¾ in. by 8½ ft.

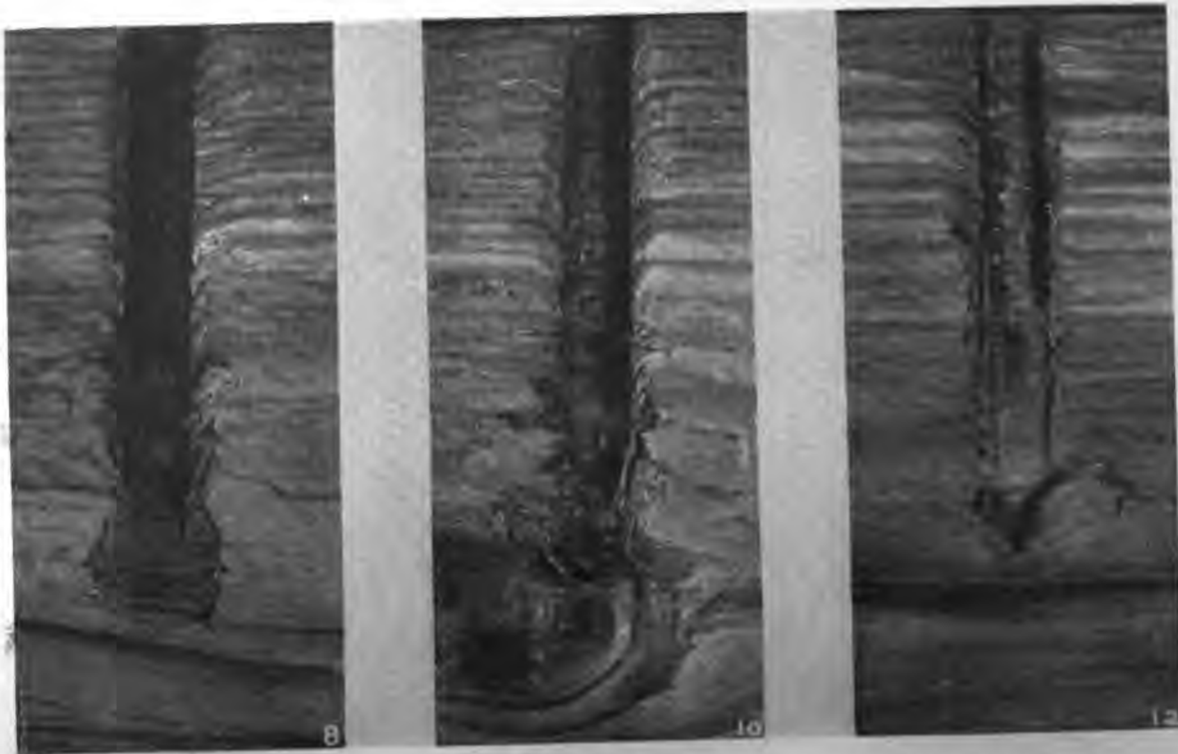
Photograph showing the rings of white oak untreated tie used in test. Note checks all around. The two vertical cracks are due to spike holes.



1-in. Chisel Point. 1-in. Sharp Point. ½-in. Blunt Point.

Hard Pine, Untreated.

Photographs showing the effects of cut spikes on fiber of untreated hard pine, driven in holes of ⅝-in. diameter, 2½ in. deep.



1⅜-in. Blunt Point. ¾-in. Blunt Point. 1½-in. Blunt Point.

Hard Pine, Untreated.

Photographs showing the effects of cut spikes on fiber of untreated hard pine, driven in holes of ⅝-in. diameter, 2¼ in. deep.

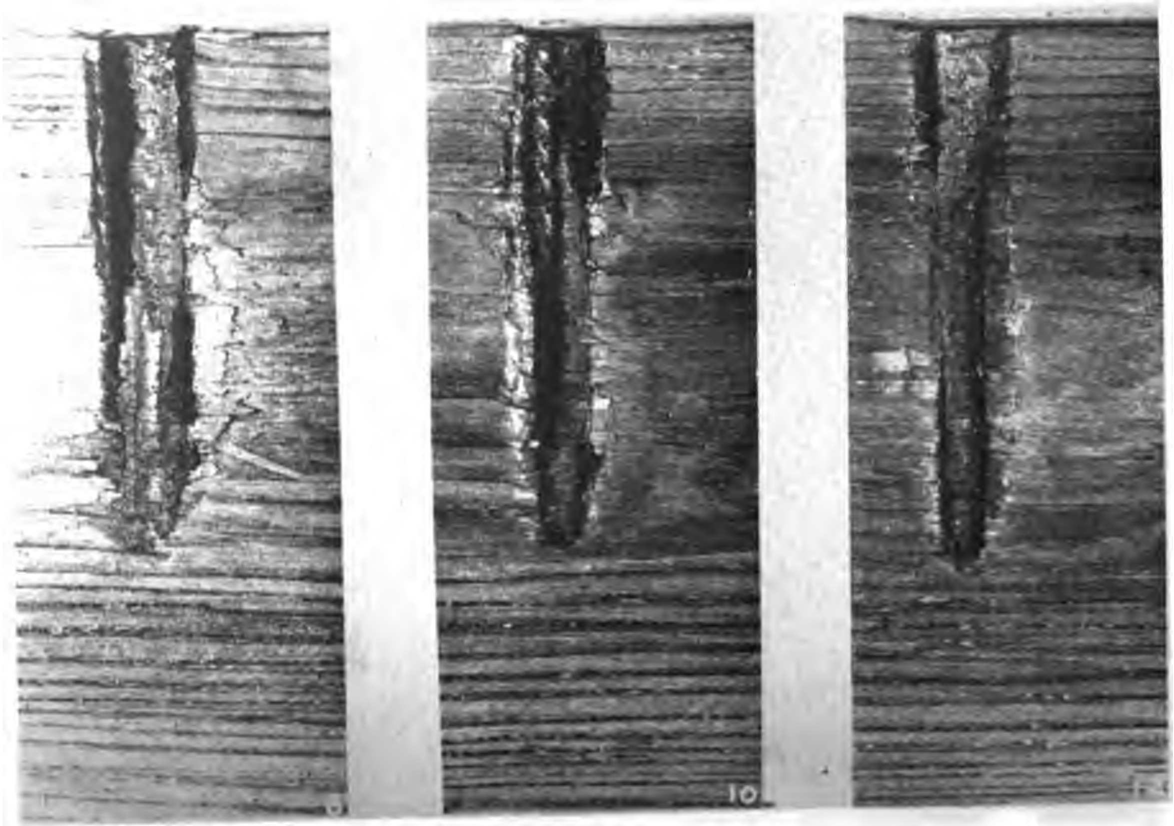
1-in. Chisel Point.

1-in. Sharp Point.

$\frac{1}{2}$-in. Blunt Point.

Hard Pine, Treated.

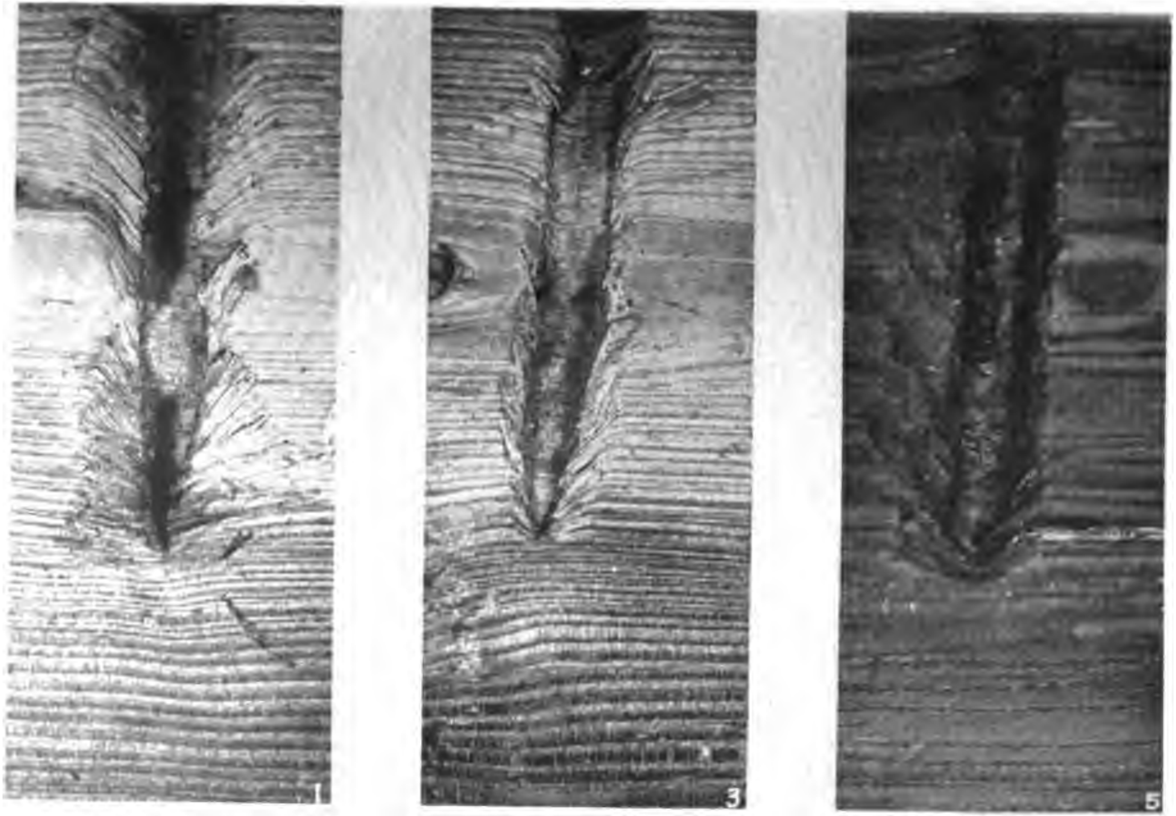
Photographs showing the effects of cut spikes on fiber of treated hard pine, driven in holes of $\frac{3}{8}$-in. diameter, 4 in. deep.



⅝-In. Blunt Point. 1¼-In. Blunt Point. 1⅝-In. Blunt Point.

Hard Pine, Treated.

Photographs showing the effects of cut spikes on fiber of treated hard pine, driven in holes of ⅝-in. diameter, 4 in. deep.



1-in. Chisel Point. 1-in. Sharp Point. ½-in. Blunt Point.

Hard Pine, Treated.

Photographs showing the effects of cut spikes on fiber of treated hard pine, driven without holes. Note how badly Nos. 1 and 5 have torn the fiber, compared to No. 3.

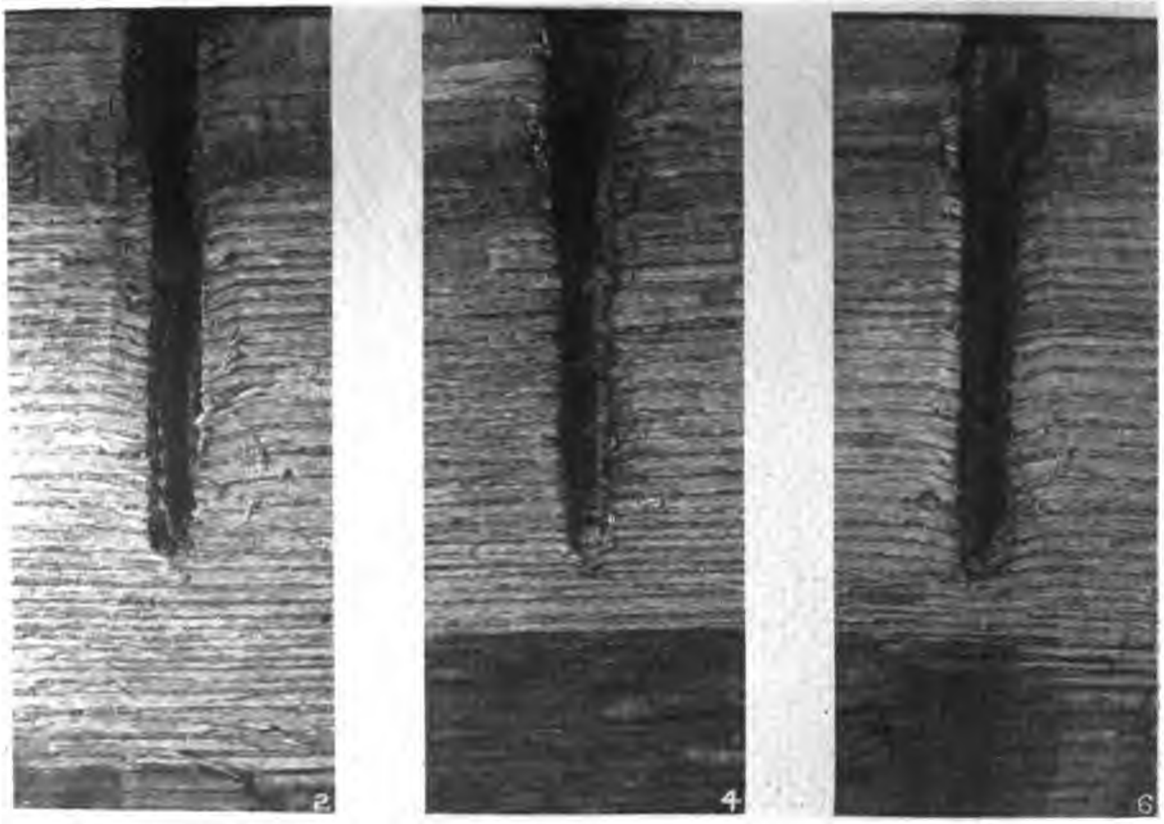
⅝-In. Blunt Point.

1¼-In. Blunt Point.

Hard Pine, Treated.

1⅜-In. Blunt Point.

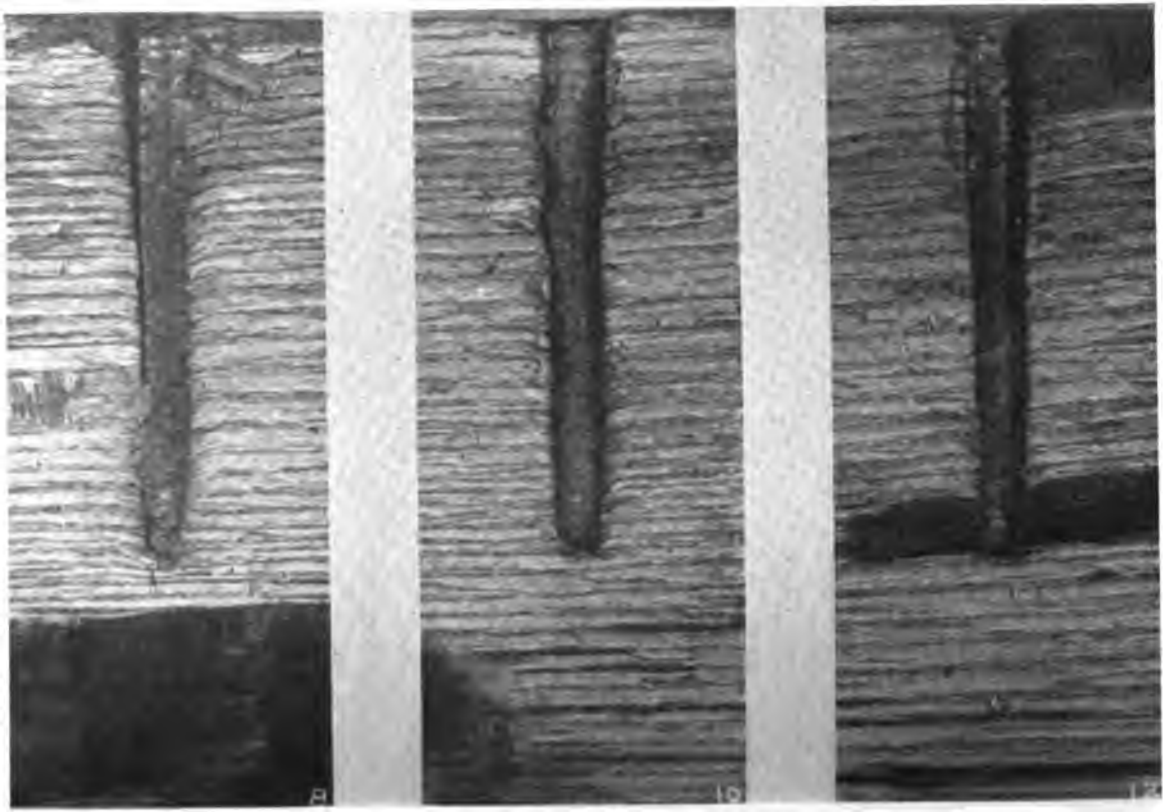
Photographs showing the effects of cut spikes on fiber of treated hard pine, driven without holes. Note the torn fiber, compared with drilled wood.



1-in. Chisel Point. 1-in. Sharp Point. ½-in. Blunt Point.

Red Oak, Treated.

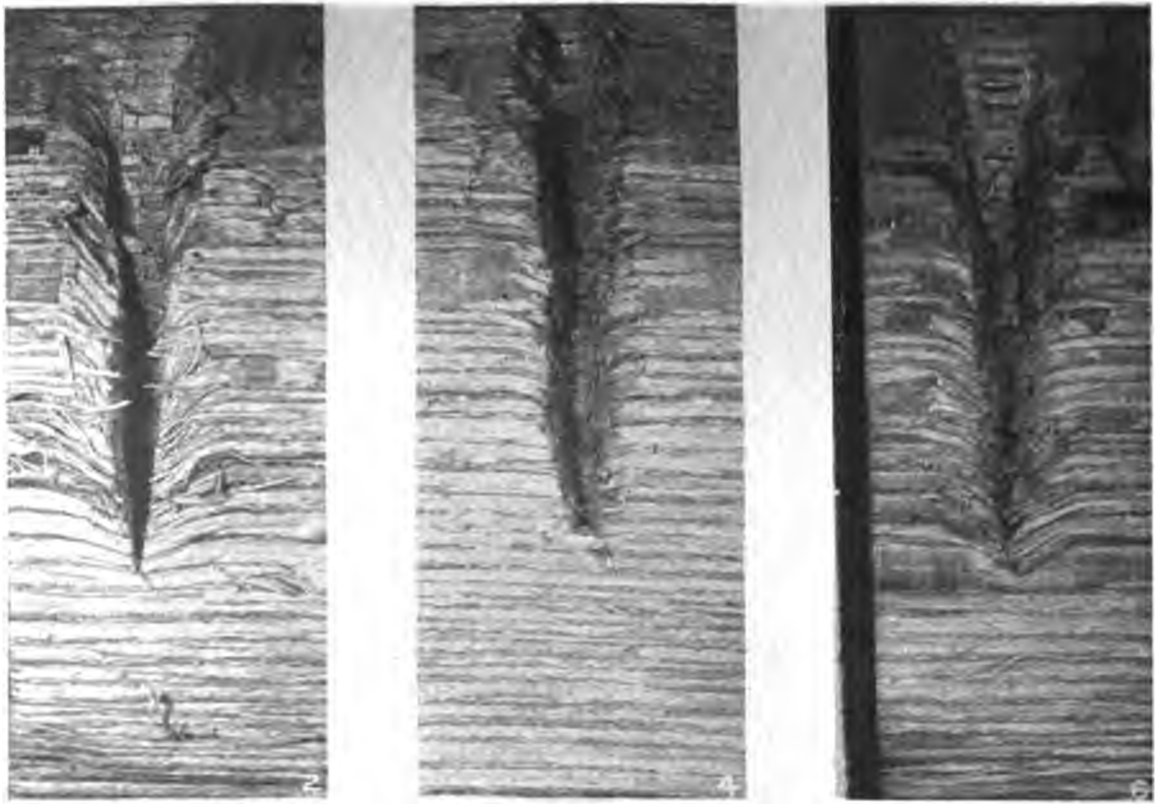
Photographs showing the effects of cut spikes on fiber of treated red oak, driven in holes of ⅜-in. diameter, 4 in. deep.



⅞-In. Blunt Point. 1¼-In. Blunt Point. 1¾-In. Blunt Point.

Red Oak, Treated.

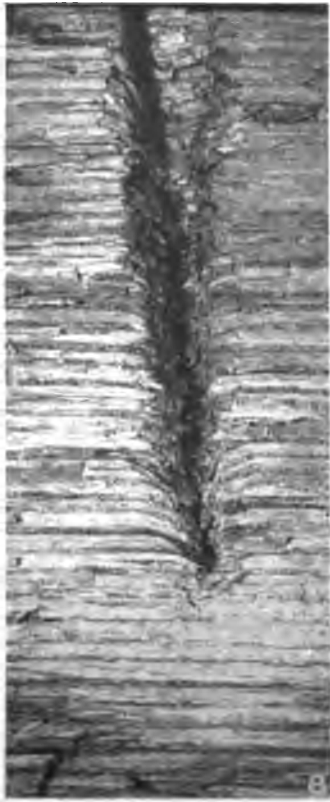
Photographs showing the effects of cut spikes on fiber of treated red oak, driven in holes of ⅝-in. diameter, 4 in. deep.



1-in. Chisel Point. 1-in. Blunt Point. ½-in. Blunt Point.

Red Oak, Treated.

Photographs showing the effects of cut spikes on fiber of treated red oak, driven without holes. Note badly torn fiber in Nos. 2 and 6, No. 4 being much better.



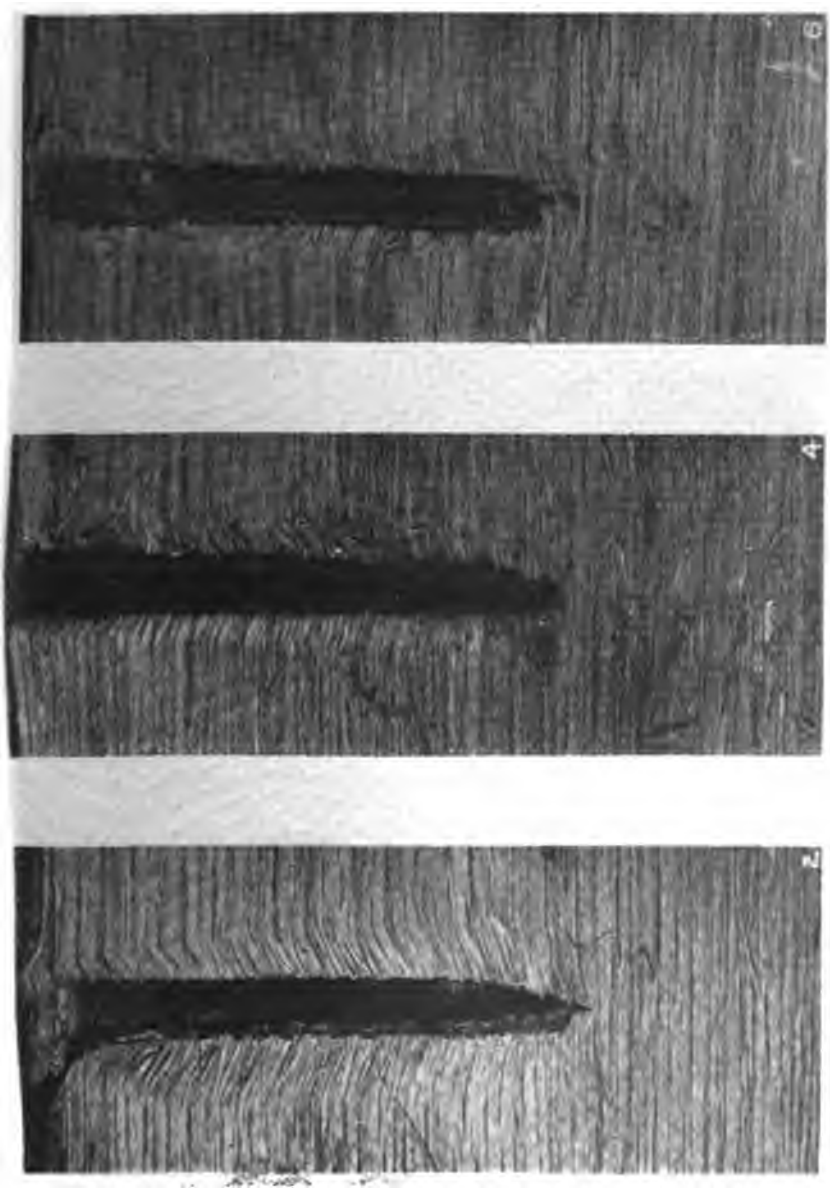
⅝-in. Blunt Point.

1¼-in. Blunt Point.

1⅝-in. Blunt Point.

Red Oak, Treated.

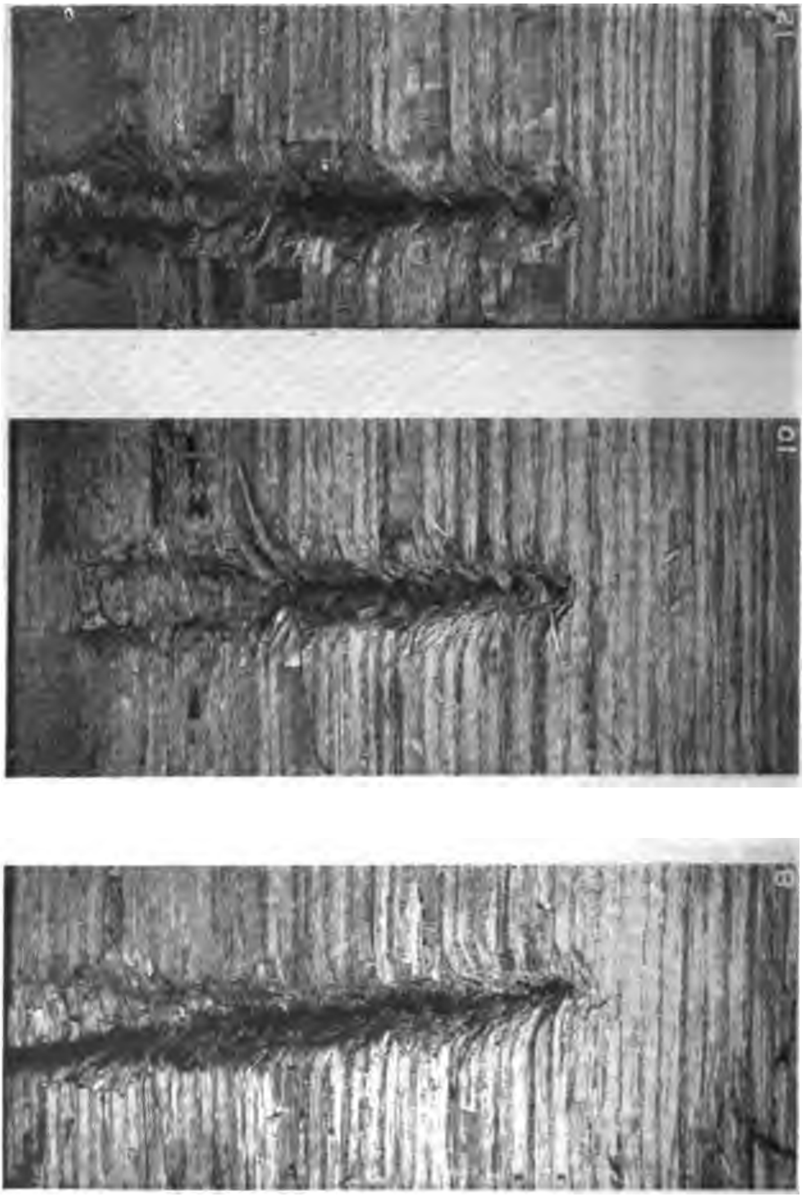
Photographs showing the effects of cut spikes on fiber of treated red oak, driven without holes. Note tearing of fiber.



1-in. Chisel Point. 1-in. Sharp Point. ½-in. Blunt Point.

White Oak, Untreated.

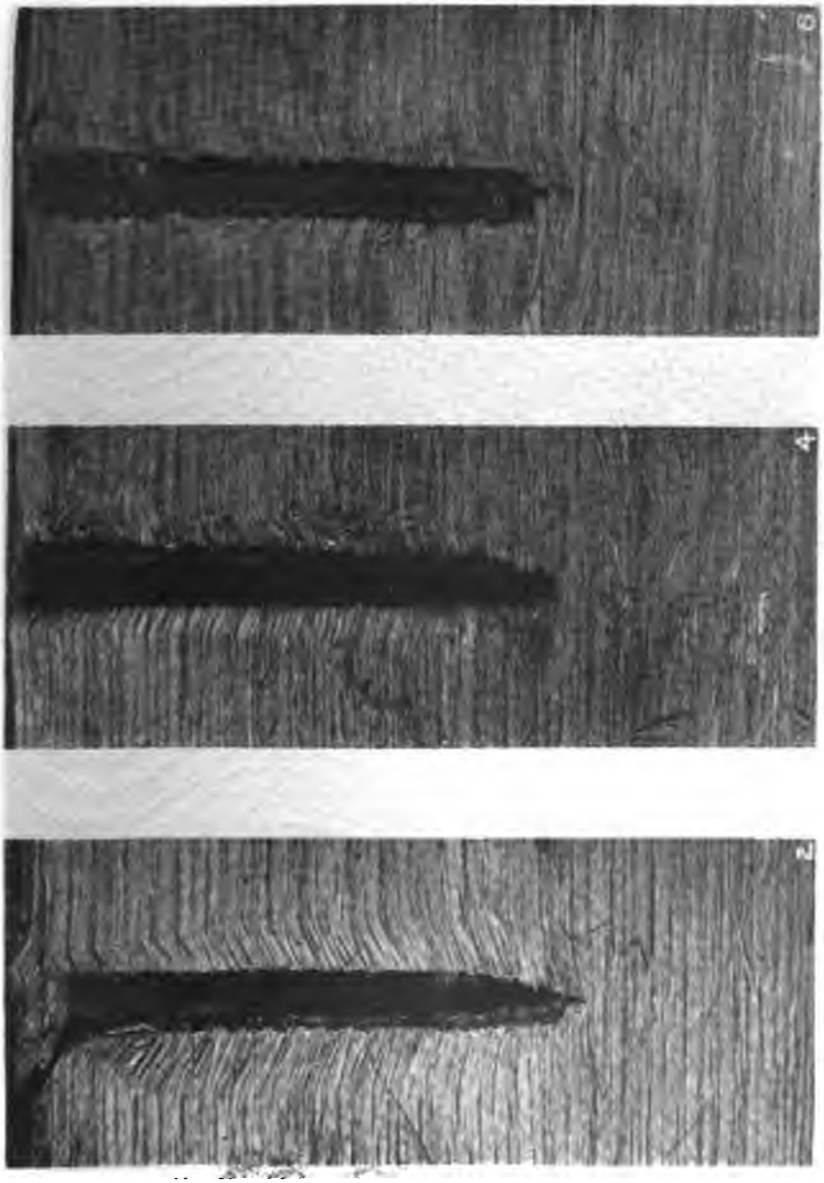
Photographs showing the effects of cut spikes on fiber of untreated white oak, driven in holes of ⅜-in. diameter, 4 in. deep.



¾-In. Blunt Point. 1¼-In. Blunt Point. 1⅜-In. Blunt Point.

Red Oak, Treated.

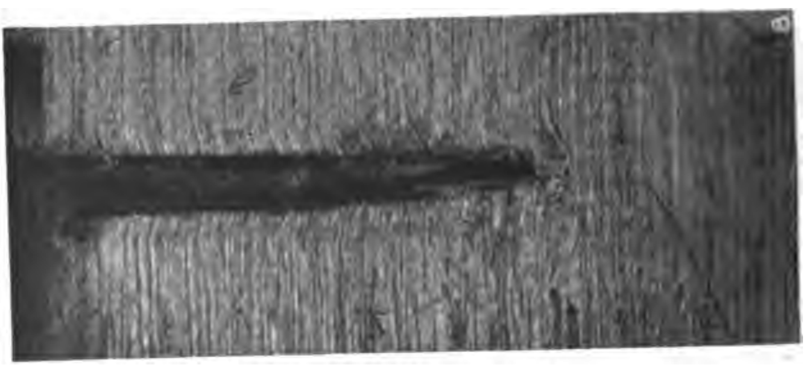
Photographs showing the effects of cut spikes on fiber of treated red oak, driven without holes. Note tearing of fiber.



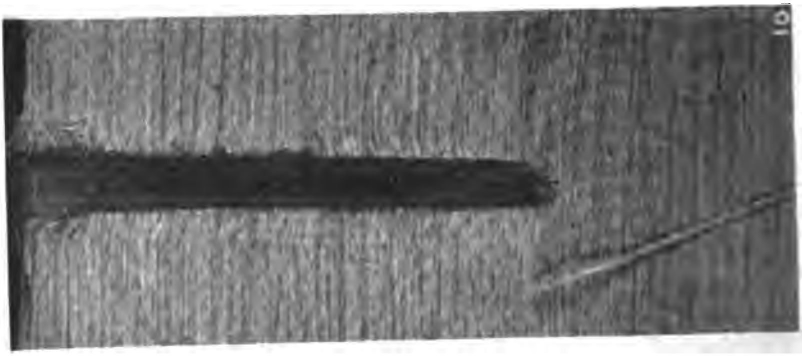
1-in. Chisel Point. 1-in. Sharp Point. ½-in. Blunt Point.

White Oak, Untreated.

Photographs showing the effects of cut spikes on fiber of untreated white oak, driven in holes of ⅜-in. diameter, 4 in. deep.



⅝-In. Blunt Point.

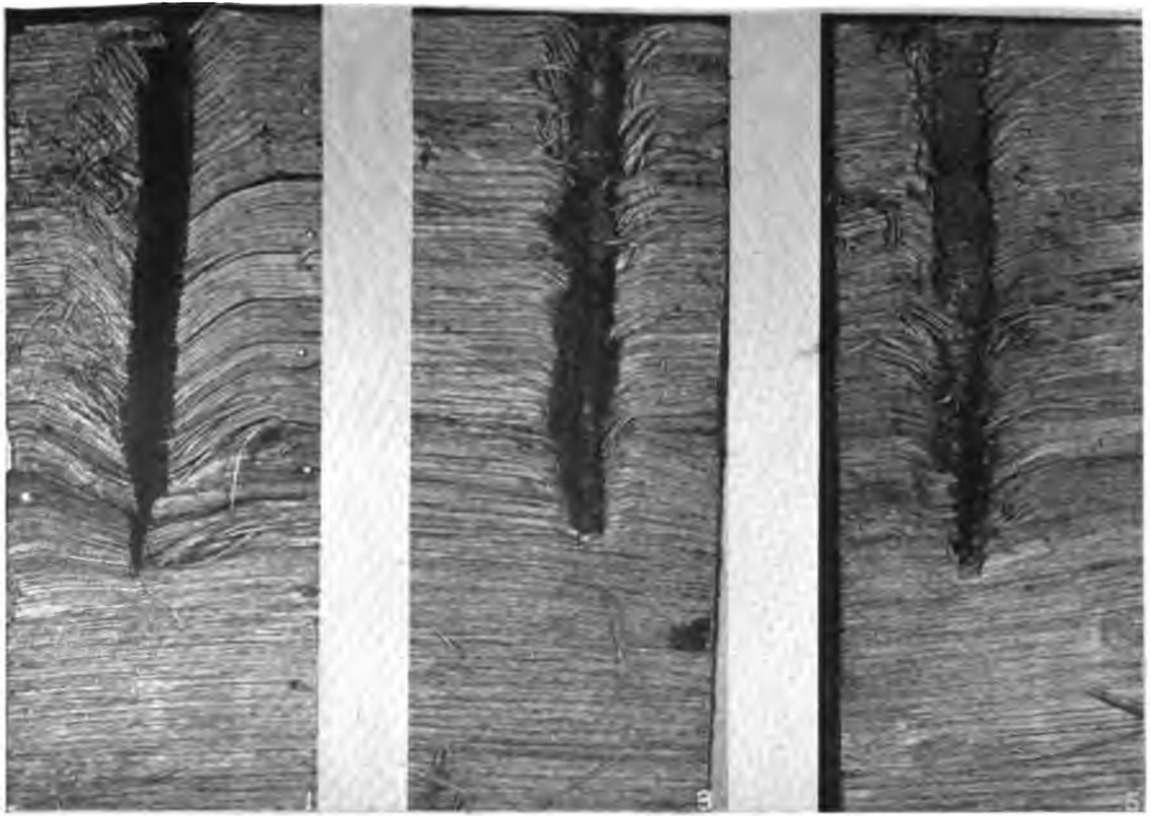


1⅛-In. Blunt Point.

White Oak, Untreated.

1⅜-In. Blunt Point.

Photographs showing the effects of cut spikes on fiber of untreated white oak, driven in holes of ⅝-In. diameter, 4 in deep.



1-in. Chisel Point. 1-in. Sharp Point. ⅛-in. Blunt Point.

White Oak, Untreated.

Photographs showing the effects of cut spikes on fiber of untreated white oak, driven without holes. Note the very badly torn fiber by the chisel-pointed spike.

Discussion.—The average values for all pulls made from 5/8 by 4-in. bored holes in all pine, red and white oak ties treated, shows the following order:

Spike Designation		Pounds	
Number.	Point.	Start.	Pull.
3 & 4	1-in. sharp	5,300	3,590
7 & 8	3/4-in. blunt	5,160	3,700
11 & 12	1 3/4-in. blunt	5,110	3,080
5 & 6	1/2-in. blunt	5,020	3,615
9 & 10	1 1/4-in. blunt	5,010	3,040
1 & 2	1-in. chisel	4,590	2,920

And the following order for tons holding power per ton of metal:

		Pounds	
		Start.	Pull.
3 & 4	1-in. sharp	9,510	6,440
11 & 12	1 3/4-in. blunt	9,400	5,670
9 & 10	1 1/4-in. blunt	8,870	5,370
7 & 8	3/4-in. blunt	8,700	6,310
5 & 6	1/2-in. blunt	8,450	6,060
1 & 2	1-in. chisel	8,020	5,110

The columns headed "start" show the initial force required to overcome all resistances and start the spike, while those headed "pull" show the average resistance of each spike after it has been started and is being drawn from the hole.

In both of the above tables the spikes are ranked upon their relative resistance to the initial pull or start. The ranking order of the different spikes based upon the average resistance after the initial start, however, would be slightly different, but is consistent in that it shows the chisel-pointed spike inferior to all the others tested.

Conclusions.—These data show that the holding power of the 1-in. chisel-pointed spike is but 86.7 per cent. that of the 1-in. sharp Goldie pointed spike, and from 1 to 10 per cent. below that of the special blunt-pointed spikes tested.

The photographs show that the injury done to the fiber of the wood is maximum with the chisel-pointed spike and a minimum with the sharp-pointed spike.

It is also greatly diminished with the blunt-pointed spikes.

The chisel-pointed spike is harder to drive straight than the others, where tie plates are not used.

There is little apparent difference in holding power of the four forms of blunt-pointed spikes tested. The pull required to start the different spikes varied less than 3 per cent.

These data substantiate results reported under test No. 84077, Spike Test—Softwood Ties, and further show that the conclusions drawn are equally applicable to the hardwoods generally used for track ties.

These conclusions were briefly as follows:

1. The Goldie spike is superior to the chisel-pointed spike not only in holding power, but on account of better alinement in the hole.

2. Better holding power and less tendency to break down the wood fiber are obtained with spikes inserted in bored holes.

Appendix B.

HOLDING POWER OF CUT AND SCREW SPIKES.

By H. B. MacFarland, Engineer of Tests, Atchison, Topeka & Santa Fe Railway System.

Object.—The object of this test was to determine:

(1) The holding power of common cut spikes and screw spikes in different kinds of wood.

(2) The relative holding power and modulus of rupture of the various kinds of wood.

(3) Their compression strength.

Material.—Nine different kinds of ties were received for test, as follows:

3 Longleaf pine,
3 Shortleaf pine;
3 Red oak;
3 Red gum,
3 Douglas fir,
3 Balsam,
3 New Mexico pine,
2 Japanese oak,
2 Ohia.

They were cut in two lengthwise to aid in handling.

The Japanese oak and ohia were sawed ties. All others were hewn. These two ties were so hard that spikes could not be screwed into a ⅝-in. hole.

WEIGHT OF TIES

Kind of Wood	Tie No. 1	Tie No. 2	Tie No. 3	Weight per cu. ft.
Longleaf pine	156 lbs., 7 oz.	156 lbs., 10 oz.	124 lbs., 3 oz.	41.1 lbs.
Shortleaf pine	110 " 7 "	98 " 3 "	103 " 7 "	41.0 "
Red oak	147 " 14 "	145 " 8 "	162 " 6 "	63.0 "
Red gum	145 " 4 "	136 " 12 "	138 " 0 "	43.5 "
Douglas fir	111 " 1 "	143 " 8 "	124 " 1 "	30.7 "
Balsam	105 " 3 "	107 " 5 "	107 " 14 "	30.3 "
New Mexico pine	136 " 7 "	134 " 0 "	152 " 0 "	29.9 "
Japanese oak	118 " 9 "	124 " 5 "	....	46.2 "
Ohia	125 " 8 "	108 " 14 "	....	47.3 "

The common spikes used were the ⅝-in. cut spike, which weighed 9½ ounces each, or 169 spikes per 100 lbs.

The screw spikes were the ⅞-in. rolled V-thread with ½-in. pitch. Diameter at bottom of thread was ⅝-in. Their weight was 19 ounces each, or 84 spikes per 100 lbs. All ties thoroughly seasoned.

METHOD.—One-half of the spikes were to be pulled immediately and the other half to be pulled one year later, with the ties exposed to weather conditions during the year.

The common spikes were driven 4¾ in. deep with a maul, under four different conditions, each tie containing:

4 spikes driven with no hole bored;
4 spikes driven with 7/16-in. hole bored;
4 spikes driven with ½-in. hole bored;
4 spikes driven with 9/16-in. hole bored.

For the screw spikes holes were bored and the spikes were screwed in for 5 in. of their length with a wrench, each tie containing:

2 spikes screwed into ⅝-in. holes;
2 spikes screwed into 11/16-in. holes.

The 200,000-lb. Olsen testing machine was used for pulling the spikes. Tie was laid across top of machine, the spike puller attached to the movable head, passed through upper crosshead and hooked onto the spike. All spikes were scrived close to the tie before pulling, and again when the maximum load was reached, thus determining the amount of draw at maximum pull. The screw spikes averaged 5/16-in. draw before the maximum load was reached, their movement being gradual until pulled out. There was little movement to the common cut spikes until maximum load was reached, then a sudden movement of from 1/64-in. to ⅛-in., depending upon the character of the wood.

33 per cent. showed a gradual creep until pulled out,
17 per cent. showed a sudden jump of 1/64-in. at maximum load,
22 per cent. showed a sudden jump of 1/32-in. at maximum load,
19 per cent. showed a sudden jump of 1/16-in. at maximum load.
4 per cent. showed a sudden jump of ⅛-in. at maximum load.

Following is a list of the holding power of the spikes in the different woods and with the different size holes bored:

COMMON ⅝-IN. CUT SPIKES.

Kind of Wood.	Pounds required to pull spike with various sizes of holes bored. No Hole.	7/16 in.	½ in.	9/16 in.
Red gum	3,610	4,230	3,220	3,020
Red gum	3,390	3,300	2,570	2,600
Red gum	3,480	3,620	3,210	3,195
Red gum	2,580	2,760	2,490	2,330
Average	3,265	3,478	2,872	2,786
Red oak	4,600	3,220	3,210	2,220
Red oak	3,940	4,020	2,700	2,710
Red oak	4,240	4,240	3,740	3,300
Red oak	3,700	4,320	3,410	3,220
Average	4,120	3,950	3,265	2,812

Kind of Wood.	Pounds required to pull spike with various sizes of holes bored. No Hole.	7/16 in.	½ in.	9/16 in.
Longleaf pine	3,580	3,780	2,900	2,890
Longleaf pine	4,770	4,200	3,660	3,710
Longleaf pine	2,400	3,600	3,470	2,320
Longleaf pine	....	3,810	2,830	2,280
Average	3,583	3,598	3,215	2,800
New Mexico pine	2,420	2,210	1,370	2,060
New Mexico pine	2,240	....	....	1,570
New Mexico pine	2,020	1,910	1,340	2,220
New Mexico pine	2,460	1,790	860	1,000
Average	2,285	1,970	1,190	1,713
Shortleaf pine	3,220	3,750	1,920	2,090
Shortleaf pine	3,520	2,830	1,990	2,070
Shortleaf pine	2,870	4,580	2,350	2,330
Shortleaf pine	3,680	4,320	2,840	2,640
Average	3,323	3,870	2,275	2,282
Douglas fir	2,990	3,720	1,910	1,880
Douglas fir	3,770	3,820	1,570	2,060
Douglas fir	2,480	2,560	1,910	2,080
Douglas fir	2,290	2,970	2,320	2,060
Average	2,883	3,268	1,928	2,020
Balsam	1,980	1,630	1,570	1,640
Balsam	2,000	2,270	1,280	1,690
Balsam	3,550	2,620	2,540	1,840
Balsam	4,340	3,640	2,260	1,700
Average	2,968	2,540	1,913	1,718
Ohia	5,010	7,930	3,920	3,800
Ohia	....	5,380	4,950	4,370
Ohia	3,620	4,910	3,750	1,400*
Ohia	....	....	....	2,860*
Average	4,315	6,073	4,207	3,108

Kind of Wood.	Pounds required to pull spike with various sizes of holes bored. No Hole.	7/16 in.	½ in.	9/16 in.
Japanese oak	6,160	6,570	3,630	5,000
Japanese oak	5,120	7,340	6,080	5,210
Japanese oak	8,060	8,370	5,000	4,110
Japanese oak	7,040	8,320	4,700	4,720
Average	6,595	7,650	4,853	4,760

*Indicates spike in crack.

SCREW SPIKES.

Kind of Wood.	Pounds required to pull spike with various sizes of holes bored. ⅝-in.	11/16-in.
Red gum	7,080	10,050
Red gum	6,920	10,570
Average	7,000	10,310
Red oak	8,640	10,010
Red oak	9,470	12,170
Average	9,055	11,090
Longleaf pine	10,490	11,660
Longleaf pine	13,450	10,320
Average	11,970	10,990
New Mexico pine	5,390	4,620
New Mexico pine	6,660	5,770
Average	6,025	5,195
Shortleaf pine	8,680	9,290
Shortleaf pine	5,750	7,420
Average	7,215	8,355

Kind of Wood.	Pounds required to pull spike with various sizes of holes bored. ⅝-in.	11/16-in.
Douglas fir	8,090	7,620
Douglas fir	9,010	9,040
Average	8,555	8,333
Balsam	5,660	5,590
Balsam	9,900	9,000
Average	7,780	7,295
Ohia	Could not screw spike in	17,370
		18,650
Average		18,010
Japanese oak	Could not screw spike in	13,280
		13,190
Average		13,235

The transverse test was made on the sections of ties in which no spikes were driven in order to determine their modulus of rupture. These pieces were placed on the bed of the testing machine on two knife edges 40 in. apart, with a 4-in. iron plate over the knife-edges. An iron plate

3 in. wide was placed on top of the tie in the center under knife-edges, which was attached to the movable head of the machine. The deflection from no load to the breaking point was also noted. The modulus of rupture was calculated by the formula $R = \frac{3PL^2}{2BD^2}$, in which P is the breaking in pounds; L the length in inches between supports; B the breadth, and D the depth of the tie.

The following are the results obtained:

TRANVERSE TEST OF TIES.

Kind of Wood.	Inches between Supports.	Load Applied.	Deflection.	Modulus of Rupture.
Douglas fir	40	40,550	1⅞ in.	4,920
Douglas fir	40	40,610	1 in.	4,910
New Mexico pine....	40	41,700	1 in.	4,420
New Mexico pine....	40	45,860	15/16 in.	4,525
Shortleaf pine	40	35,510	15/16 in.	7,290
Shortleaf pine	40	28,470	⅝ in.	5,645
Balsam	40	26,140	¾ in.	4,270
Balsam	40	30,000	½ in.	3,380
Red gum	40	36,450	1 in.	5,460
Red gum	40	41,950	1 in.	5,330
Red oak	40	30,680	¾ in.	6,020
Red oak	40	37,270	⅞ in.	8,610
Longleaf pine	40	47,160	⅞ in.	5,880
Ohia	32	50,910	⅝ in.	8,480
Japanese oak	30	50,000	½ in.	7,580

COMPRESSION TEST.—The ties were hewn so unevenly that it was found impossible to get comparative results without squaring up a short section. Pieces 18 in. long were cut from the ends of the ties used for transverse test and planed to 5⅜ by 7½ in. These pieces were then placed flat in the testing machine, a section of railroad rail placed across them and the pressure applied to the rail sufficient to imbed it 3/16-in. and ⅜-in. in the tie.

The following table shows the pressure required to sink the rail in the tie, also pounds per square inch pressure on the section. The weight per cubic foot of timber was calculated from the short sections which were planed.

COMPRESSION TEST.

Kind of Wood.	Pounds to sink rail 3/16 in. deep.	Pounds per sq. in.	Pounds to sink rail ⅜ in.	Pounds per sq. in.
Shortleaf pine	39,050	1,225	47,190	1,480
Longleaf pine	27,405	860	34,560*	1,082
Douglas fir	30,880	968	34,440	1,080
New Mexico pine......	26,060	816	31,160	977
Balsam	23,560	739	27,560	863
Red gum	34,640	1,088	42,120	1,320
Red oak	41,670	1,306	53,350	1,670
Japanese oak	63,860	2,000	80,700	2,530
Ohia	76,720	2,400	88,710	2,780

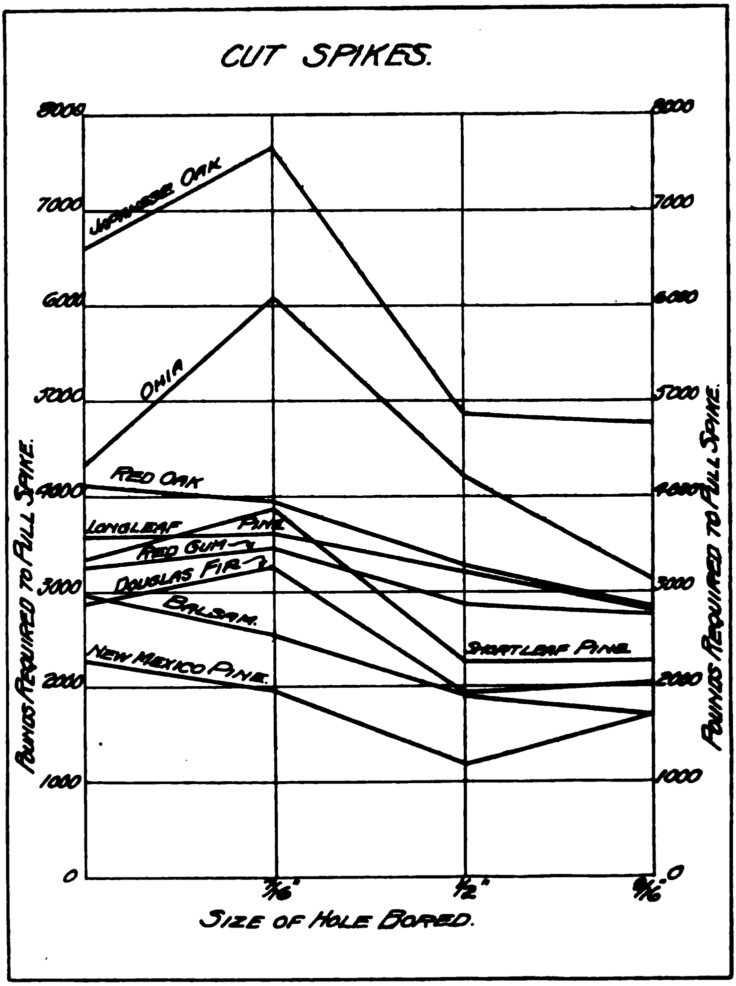
*Indicates tie split.

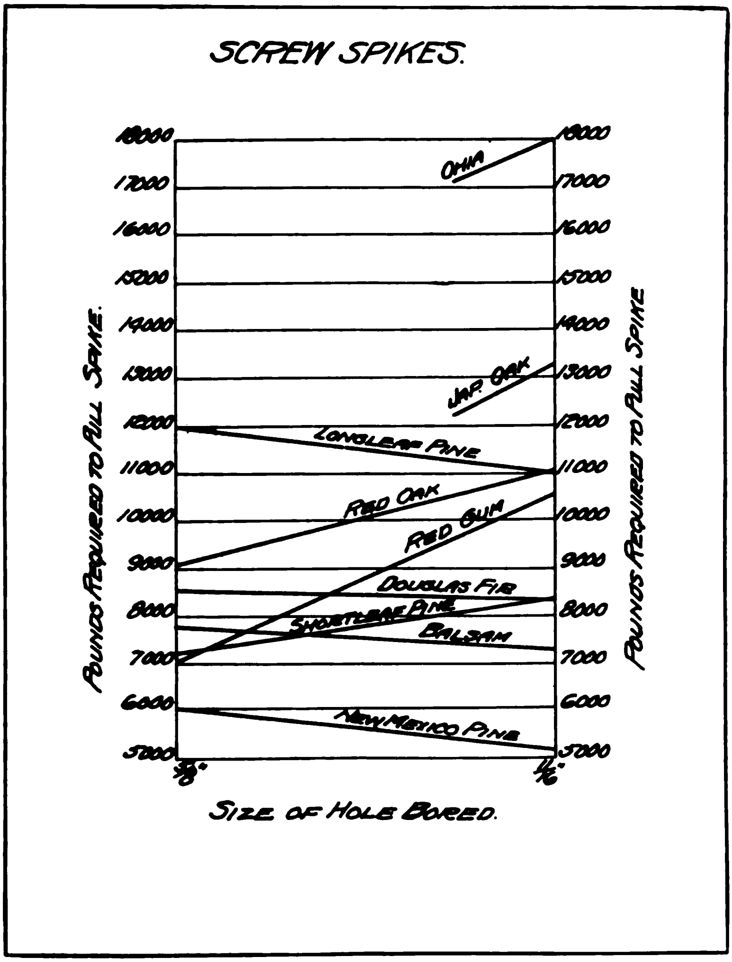
The red gum, balsam, longleaf pine and red oak fibers were not broken at all by the rail in the compression test, which indicates a very elastic fiber in the wood. The Japanese oak and ohia show a very slight breaking of the fiber.

Douglas fir, shortleaf pine and New Mexico pine presented very brittle fibers, which were broken considerably by the rail section when under compression.

The relative weight of the cut spikes as compared with the screw spikes is 1 to 2, and their relative maximum holding power averages 1 to 2½ respectively, thus indicating an advantage of 25 per cent. for the screw spike over that of the cut spike, equal weights of metal being considered. It will be noted from the accompanying curves that in the majority of cases the cut spikes driven in the 7/16-in. holes require the greatest force to remove them. The longleaf pine exhibits about the same holding power with no hole and with 7/16-in. hole, while the red oak, balsam and New Mexico pine display a somewhat higher power with no hole bored for the spike.

With the screw spikes we have but seven compressions to make, since it was impossible to screw the spikes in ⅝-in. holes in the ohia and Japanese oak woods. In these seven cases, however, the red oak and the red gum, which are the hardwoods, reveal a much greater holding power with the spikes screwed into the larger hole, while the longleaf pine, Douglas fir, balsam and New Mexico pine, which are softwoods, the holding power of the spikes is somewhat higher with the smaller hole, although the difference is not so marked as in the case of the hardwoods.


CUT SPIKES.
8000
7000
6000
5000
4000
3000
2000
1000
0
JAPANESE OAK
OHIA
RED OAK
LONGLEAF PINE
RED GUM
DOUGLAS FIR
BALSAM.
NEW MEXICO PINE.
SHORTLEAF PINE
POUNDS REQUIRED TO PULL SPIKE.
7/16"
1/2"
9/16"
SIZE OF HOLE BORED.

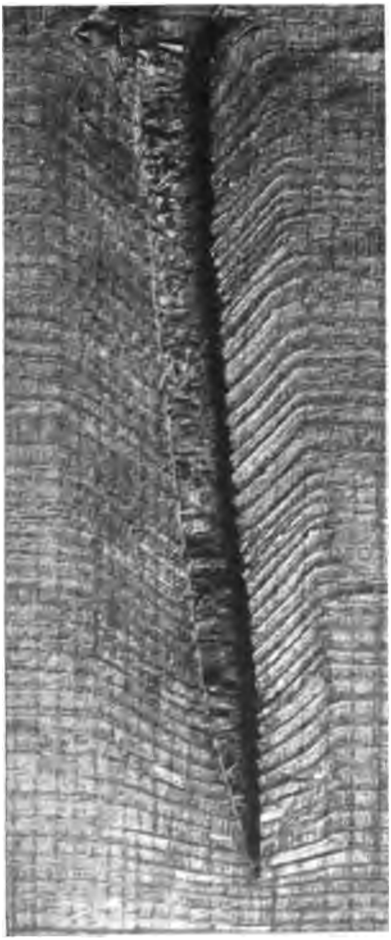

SCREW SPIKES.
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
POUNDS REQUIRED TO PULL SPIKE.
OHIA
JAP. OAK
LONGLEAF PINE
RED OAK
RED GUM
DOUGLAS FIR
SHORTLEAF PINE
BALSAM
NEW MEXICO PINE
SIZE OF HOLE BORED.

Appendix C.

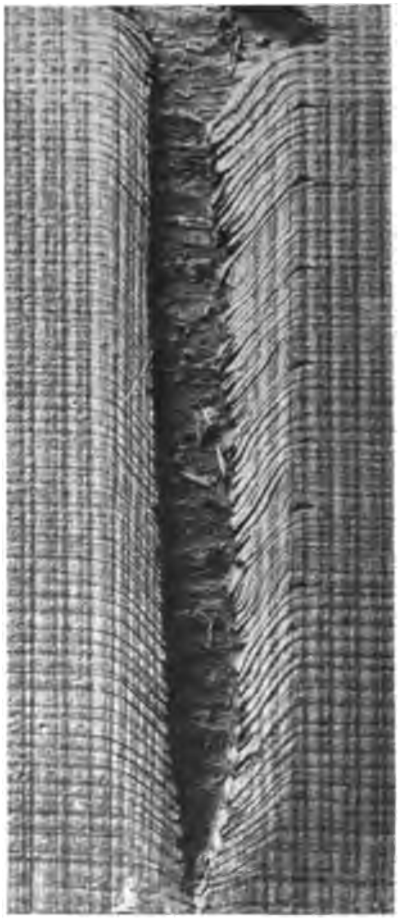
EFFECT OF DESIGN OF TRACK SPIKES AND TIE PLATES ON THE DURABILITY OF TIES.

(From Report to R. J. Parker, General Superintendent, Atchison, Topeka & Santa Fe Railway.)

SERIES I.—Samples of ties showing the driving of cut spikes, being evidence as to the damage done to ties by the driving of our present cut spikes, and would seem to be an unanswerable argument in favor of the boring of ties before they are inserted in the track.

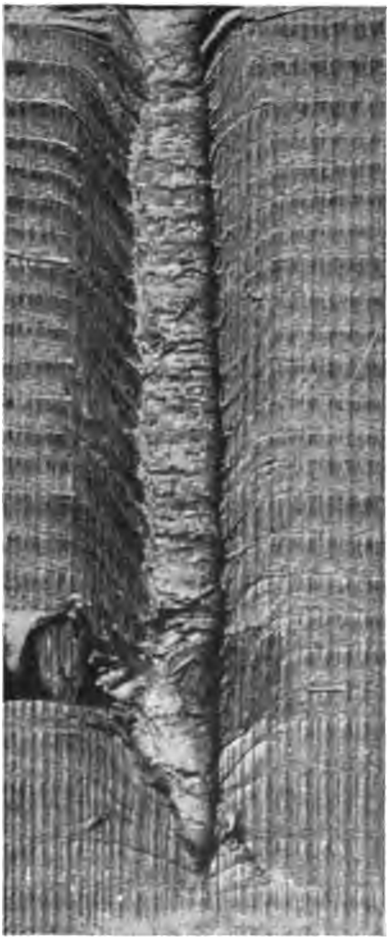


White Oak, Untreated.
Common Spike, 9/16 by 9/16 in. Pulls 9,630 lbs.

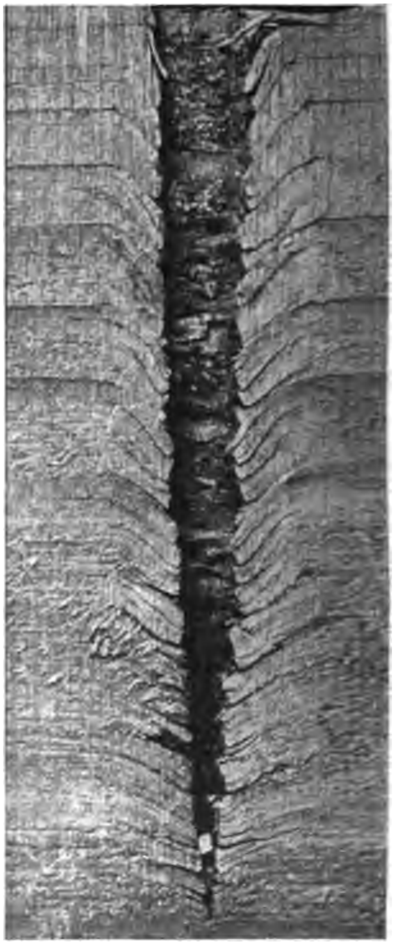


Spruce.
Common Spike. Pulls 3,030 lbs.

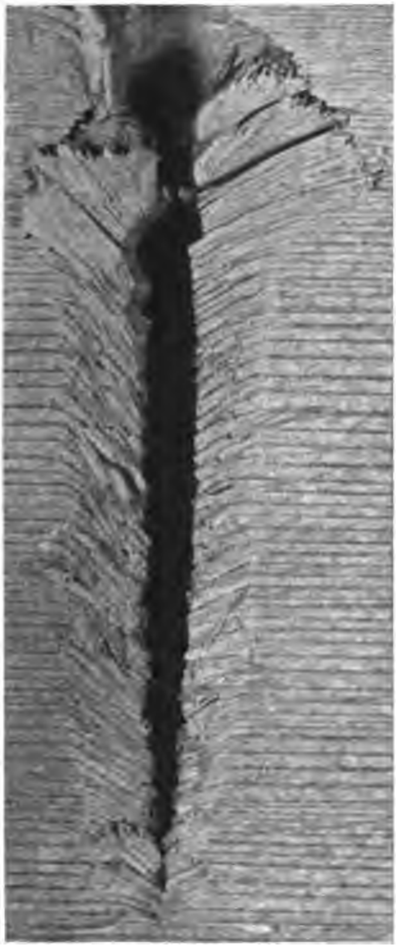
Longleaf Pine Tie.
Treated by Rueping process and spike driven after treatment, in an unbored hole.



Fir.
Common Spike. Note direction grain line of spike. Pulls 3,957 lbs.



Loblolly Pine.
Creosoted Common Spike. Pulls 2,448 lbs.

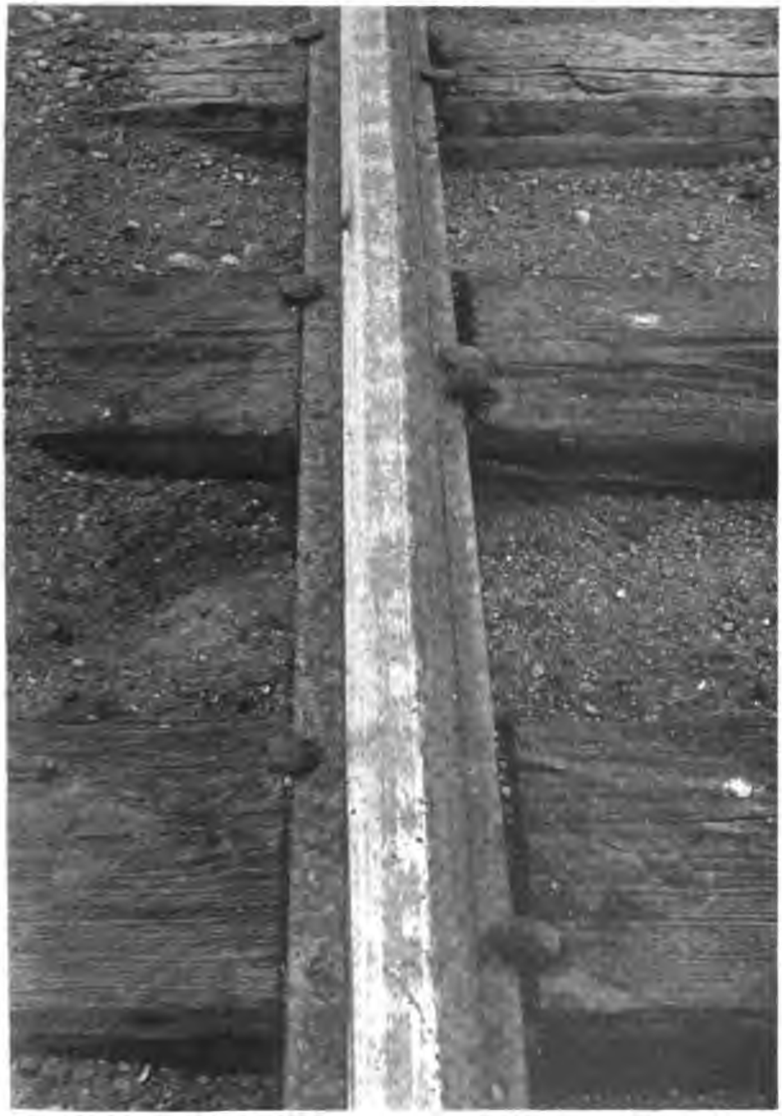


Chisel Point. Showing effects of cut spike inserted in redwood. No hole bored. Note badly broken fiber caused by chisel-point spike.

Chisel Point Spike. Showing effects of cut spike inserted in cedar; no hole borel. Note badly broken fiber caused by chisel point.

Series 2.—Views showing injury to ties by rail cutting and spike driving. Especial attention is directed to view No. 22, Arkansas River Division, A., T. & S. F. Railway, showing 1910 treated ties with cut spikes without plates. Note the ruination of these ties in three years, also View 4, same division, especial attention being directed to 1912 ties in the foreground of the picture, which are already beginning to show signs of abuse for lack of plates, then compare this with the View 2, Missouri Division, in which 1912 ties are inserted with plates.

View showing injury to ties by rail cutting and spike driving. View 4. Arkansas River Division. Note especially two 1912 ties in foreground badly abused account lack of plates after less than one year's service.



View showing injury to ties by rail cutting and spike driving. View 3, Arkansas River Division. Same as View 22.

View showing injury to ties by rail cutting and spike driving. View 22, Arkansas River Division, 1910 treated ties, with cut spikes without plates. Note especially ruination of ties in three years from this cause.

View showing injury to ties by rail cutting and spike driving. View 1, Arkansas River Division, 1907 ties, cut spikes without plates.

View showing injury to ties by rail cutting and spike driving. View 3. Missouri Division. Cut-spike track with tie plates, where zinc ties used same as in View 2. These ties being laid out of face when track was constructed and right at end of the tie shown in No. 2. Observation on ground would indicate would get at least four years more service from the ties than those without plates, and if ties had been high-class creosoted ties in first instance, this would be increased.

View showing injury to ties by rail cutting and spike driving. View 4, Missouri Division. Ties inserted in 1906, cut spikes without plates.

View showing injury to ties by rail cutting and spike driving. View 1, Missouri Division. 1904 ties, cut spikes without plates.

View showing injury to ties by rail cutting and spike driving. View 2, Missouri Division. Note first four ties in foreground and compare these with condition of 1912 ties in previous picture, demonstrating value of tie plates.

View showing injury to ties by rail cutting and spike driving. View 21, Colorado Division, showing ties with and without tie plates.

SERIES 3.—Showing cut spikes with and without tie plates and with and without rail anchors. In this connection, note View 2 of Arkansas River Division, A., T. & S. F. Railway, showing the damage from rail cutting and condition of track, account of skewing of the ties.

View 23, Illinois Division, showing cut-spike track with tie plates and rail anchors.

View 24, Illinois Division, cut-spike track, tie plates and rail anchors.

View 1, Albuquerque Division, cut spikes, tie plates, Japanese oak ties. Note the skewing.

View 2, Arkansas River Division. Cut-spike track without tie plates or rail anchors. Note the damage to tie from rail cutting and condition of track account skewing of tie.

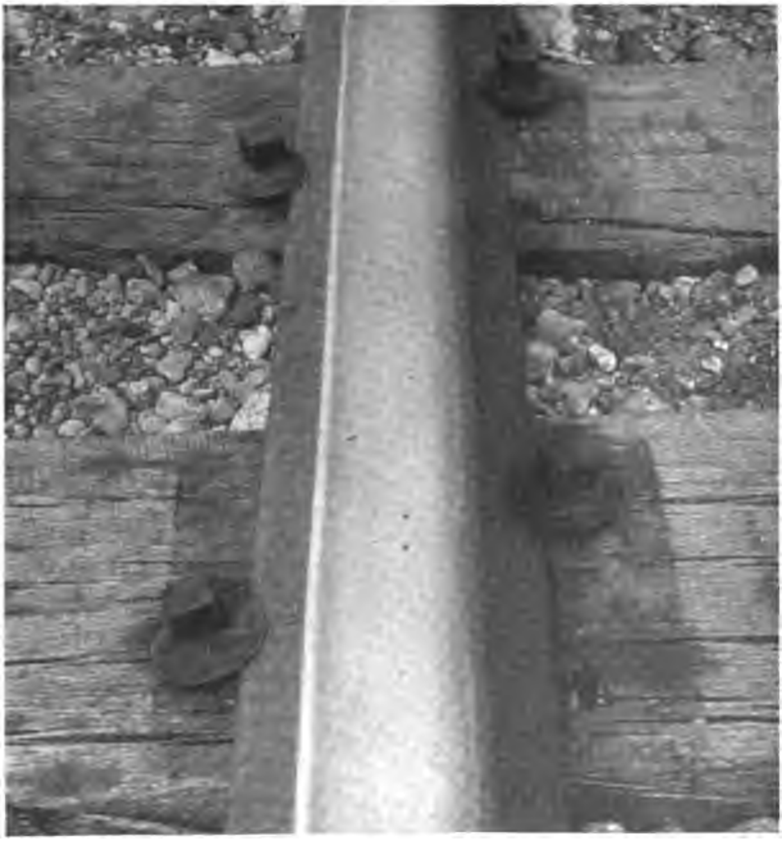
SERIES 4.—Showing several views on the Illinois Division, A., T. & S. F. Railway, screw-spike track with and without tie plates.

No. 1, View 11, Illinois Division. Screw spikes inserted with plates, without shoulder.

View 20, Illinois Division, same as above. Note, these were inserted 1909, and ties have to be spaced once a year.

View 19, Illinois Division. Screw spikes inserted with plates without shoulder.

View 21, Illinois Division. Screw spike; joint ties inserted without tie plates. Note skewing, which is approximately 4 in. and is average of the lot.



View 22, Illinois Division, showing screw spikes used opposite joints without tie plates.

SERIES 5.—Screw-spike track on the Missouri Division, A., T. & S. F. Railway. Note the first three views, Nos. 21, 19 and 20, screw spikes inserted in 1908, and View 20, showing the movement of the rail in five years, 2⅝ in. without the spikes ever having been touched, and Views 12 and 11, showing screw spikes on ties in quarters and centers, inserted in 1912, View 11 showing the rails having moved 4 in., which will seem to be an argument in favor of a solid screw-spike track.

View 21, Missouri Division. 1908 screw spikes, never touched.

View 19; 1908 screw spikes, never touched.

View 20; 1908 screw spikes, never touched. Note movement of rail in five years,, or 2⅝ in.

View 12; 1912 screw spikes on ties in quarter and centers.

View 11; 1912 screw spikes on ties in quarter and centers. Note that in one year these rails have moved 4 in.

SERIES 6.—Showing Standard Santa Fe construction, with screw spikes.

View 20, Western Division. Sawn pine, standard construction screw spikes.

View 19, Western Division. Hewn pine, standard construction screw spike

View 22, Western Division. Hewn gum, standard construction screw spikes.

View 1, Western Division. Ohia hewn ties, standard construction screw spikes.

View 24, Albuquerque Division. Eucalyptus ties, standard construction screw spikes.

View 12. Albuquerque Division. Japanese oak, standard construction screw spikes.

View 2. Western Division. One set hewn gum switch ties, screw spikes; standard construction screw spikes.

View 23, Missouri Division. Gauntless track with screw spikes, standard construction screw spikes.

View 24, Missouri Division. Gauntlet track, with screw spikes; standard construction screw spikes.

SERIES 7.—View 24, Western Division, A., T. & S. F. Railway, standard Santa Fe screw-spike track, installed 1910, upon which wreck occurred account of brake beam being down in 1911. Note where wheels hit ties in this track, edges of plates, spikes and joints were considerably trimmed by impact from wheels, and, while train ran 18 rail lengths before stopping, there was only one tie taken out after accident and gage was absolutely not disturbed.

As compared with what would have occurred, had cut spikes been used, this seems to be a strong argument in favor of the screw spike.

View 24, Western Division. Standard screw spike construction, installed 1910, upon which wreck occurred, account brake beam being down, in 1911.

SERIES 8.—View showing dowelled ties with screw spikes. Note especially Views 12, 4 and 3, showing a section of a tie that was dowelled and sections of the same tie cut showing the application of the screw spike in same.

No. 1, View 22. Red Oak Tie. Second-hand, dowelled with oak dowels in the field by the Kendrick Dowelling Machine.

No. 2, View 12. New sawn pine tie, dowelled in 1910 by the Kendrick Dowelling Machine, and put into the Hutchinson track.

No. 3, View No. 4. Section through dowel of same tie as shown in No. 2, View 12.

No. 4, View 3, showing contact of screw spike in same tie.

No. 5, View 4, Albuquerque Division, showing two redwood and two cedar ties dowelled in 1910.

No. 6. View 11, Western Division, showing stretch of sawn pine ties, dowelled in 1910.

SERIES 9.—Some specialties used in construction on the experimental track between Sylvia and Kinsley.

Specialties used in Experimental Track, Sylvia to Kinsley. View 21. Western Division, Weber Joint with screw spike requiring lugs.

Specialties use in Experimental Track, Sylvia to Kinsley. View 21, Western Division, top view, same point.

No. 3, View 23, Western Division. Beddoe Joint with screw spikes. Roadmaster claims better service with screw spikes than Weber.

No. 4, View 1, Western Division. Bonzana Joint with screw spikes.

No. 5, View 2, Western Division, showing Positive tie plate with screw spike.

Specialties used in Experimental Track, Sylvia to Kinsley. View 21, Western Division, showing Security tie plates with screw spikes.

View 22, Western Division, showing Morse tie plate and screw spike. Roadmaster says cannot keep bolts tight on this plate.

Specialties used in Experimental Track, Sylvia to Kinsley. View 20, Western Division, showing YY tie plate, Adrian modified style.

SERIES 10.—Views 23 and 24, Colorado Division, A., T. & S. F. Railway, showing conditions which are the result of coal-burning engines cleaning fires on unprotected track. These ties were treated with oil in 1909, which demonstrates that it is quite an expensive proposition and suggests in itself that some remedy should be applied, such as the insertion, say of a number of steel ties, to be placed at each end of a passing track, painted white, so that they would be readily seen by the engineer, and an order issued compelling him to pull to that point before cleaning out firebox.

No. 2, View 24, Colorado Division. Oil-treated ties, inserted 1909.

No. 1, View 23, Colorado Division.

SERIES 11.—Views showing application of the Betts anti-creeper tie plate, as installed on the Eastern Division, A., T. & S. F. Railway. Also effect of the application of 6-in. tie plates to 7-in. ties. A very strong argument in favor of the 7-in. tie plates.

Betts anti-creeper tie plate, on curve just west of Turner Station.

Betts anti-creeper tie plate, on curve just west of Turner Station.

Betts anti-creeper tie plate, just outside Holliday Station.

Betts anti-creeper tie plate, just outside Holliday Station.

Six-in. tie plates under 85-lb. rail.

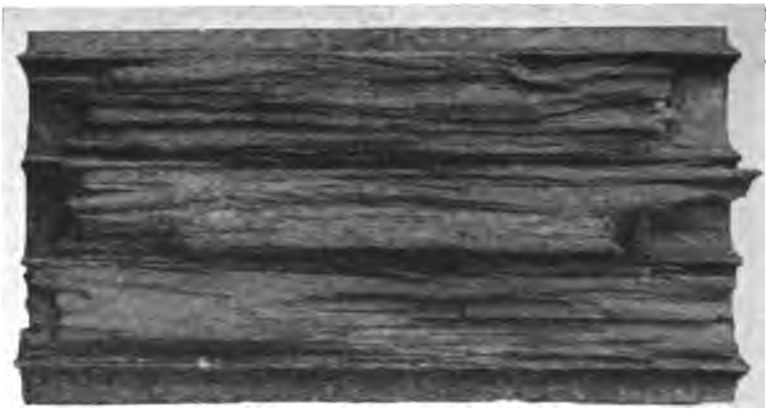
Six-in. tie plates under 75-lb. rail.

Six-in. tie plates under 75-lb. rail.

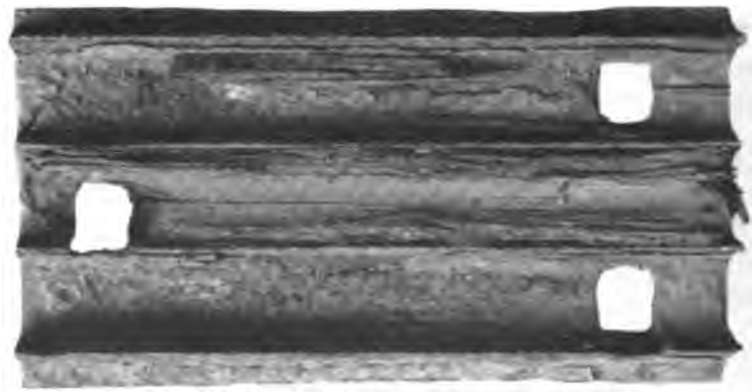
SERIES 12.—Views showing effect upon the tie of the old-style deep-ribbed Wolhupter tie plate. Views 1 and 2, showing two ends of the tie from which a tie plate was removed, showing the indentations and decay of wood resulting from the deep abrasions. Views 3 and 4 show old-style Wolhaupter tie plates that have been removed from ties, the decayed wood clinging to them between the ribs.

Series 12. View 1.

Series 12. View 2.



Series 12, View 3.



Series 12, View 4.

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS

C. H. Stein, *Chairman;*
R. B. Abbott,
H. E. Billman,
E. T. Brown,
B. M. Cheney,
A. C. Copland,
F. N. Crowell,
Arthur Crumpton,
J. T. Frame,
L. E. Haislip,
G. E. Boyd, *Vice-Chairman;*
C. M. James,
Maro Johnson,
L. C. Lawton,
J. B. Myers,
G. L. Moore,
C. H. Splitstone,
J. A. Stocker,
W. F. Strouse,
W. D. Williams,

Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned by the Board of Direction for consideration:

(1) Continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability.

(2) Concrete and metal for signs and signals as compared with wood.

(3) Concrete and metal as compared with wood for fence posts.

A general Committee meeting was held in Chicago at the Association rooms on Monday, June 9, 1913. There were present H. E. Billman, Maro Johnson, L. C. Lawton, Arthur Crumpton, L. E. Haislip, W. F. Strouse, W. D. Williams, C. H. Stein.

The subjects assigned were discussed and the following Sub-Committees appointed:

Subject No. 1, Proper Quality of Fence Wire:

W. D. Williams, Chairman;
J. A. Stocker,
L. C. Lawton,
F. N. Crowell,
L. E. Haislip,
B. M. Cheney.

Subject No. 2, Concrete and Metal for Signs and Signals:

W. F. Strouse, Chairman;
R. B. Abbott,
C. M. James,
A. C. Copland,
G. L. Moore,
J. B. Myers,
C. H. Splitstone,
C. H. Stein.

Subject No. 3, Concrete and Metal for Fence Posts:

Maro Johnson, Chairman;
H. E. Billman,
G. E. Boyd,
E. T. Brown,
J. T. Frame,
Arthur Crumpton.

(1) INVESTIGATION OF WAYS AND MEANS FOR SECURING A PROPER QUALITY OF FENCE WIRE.

The Secretary of the Association, under date of September 11, 1913. issued a circular prepared by the Committee to the various railroads represented in the Association, making inquiries in regard to present practices and recent developments, for the purpose of securing a proper quality of fence wire. Only 35 replies were received, and the information imparted is so vague and unsatisfactory that it will probably be of interest to furnish a statement of the inquiries made, with a summary of the replies received:

Question 1. *Kindly send copy of your specifications of fence wire for right-of-way purposes.*

25 have no specifications.
5 use manufacturers' specifications.
2 use Association's recommended specification for galvanizing.
3 have had no experience with wire fencing.

Question 2. *Have you conducted any experiments that serve as a basis for your conclusions in preparing such specifications?*

21 no.
12 do not reply.
2 from actual service.

Question 3. *Furnish such data as you possess that enabled your company to reach such conclusions.*

3 from observation.
8 no data.
24 do not reply.

Question 4. *Are you securing wire fencing that complies with these specifications, and from whom?*

11 furnish names of various manufacturers.
4 report "No."
20 do not reply.

Question 5. *Cost of wire fencing f. o. b. line of road?*

15 reply average 31 6-10c per rod.
14 reply average 32 5-10c per rod.
1 replies 53c per rod.
5 do not reply.

Question 6. *Actual or estimated life of wire fencing that you are now using.*

11 furnish no data.
2 reply 7 years.
11 reply 6 to 15 years.
2 reply 25 years.
7 reply 15 years.
1 replies 8 years.
1 replies 30 years.

Question 7. Actual life of wire fencing purchased before the adoption of your specifications.

30 reply "No data."
2 reply 8 to 10 years.
1 replies "barb wire 25 to 30 years."
1 replies 10 years.
1 replies 5 to 6 years.

Question 8. Description of fencing or specifications covering same, that you were using prior to the adoption of your present specifications.

26 do not reply.
4 reply "barb wire."
5 used manufacturers' specifications.

Question 9. Please send small sample of the wire fencing that has given you extra good service.

30 sent no samples.
4 submitted No. 9 special galvanized wire.
1 sent sample of barb wire.

Question 10. Have you made any analysis of your wire fencing; if so, kindly furnish data.

35 reply "No."

Question 11. Have you made any investigations to show how evenly protective coating is distributed? If so, please give results.

35 reply "No."

Question 12. Have you ever used fencing wire that was made of puddled iron or of ingot iron? If so, please give your experience.

35 reply "No."

A careful analysis of the replies received failed to develop anything of a new or tangible nature, and the Committee feels that it can add nothing of value to what has already been presented to the Association upon this subject. It, therefore, reluctantly concludes that it would be well to discontinue any further consideration of the matter for the present, but permit a sufficient time to elapse to enable those few roads that are trying to make some progress in the development of a better quality of fencing wire to conclude their investigations. The subject may be revived in the course of the next couple of years with the hope of some accomplishmnet.

(2) CONCRETE AND METAL FOR SIGNS AND SIGNALS AS COMPARED WITH WOOD.

A meeting of the Sub-Committee was held in Baltimore, Md., August 3, 1913, at which the following members were present: W. F. Strouse, Chairman; R. B. Abbott, A. C. Copeland, C. H. Splitstone, C. H. Stein.

A circular submitting the following inquiries for information was prepared and sent by the Secretary of the Association to 400 representatives of railroad companies in the United States, Canada and Mexico:

CROSSING SIGNS

Name of Railroad	Post	Depth in Ground	Blades	Angle from Horizontal	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription and other Information
Atchison, Topeka & Santa Fe..	Wood 8"x8"x17'-0"	5'	12"x6'-0"	45°	White	Black 7" high	$5.75	$6.50	**"Railroad Crossing" on blades. Base of** post creosoted. Post painted brown where not treated.
Baltimore & Ohio System.....	Wood 7"x7"x16'-6"	4'	11"x6'-8"	26°30'	White	Black 9" high	5.00	6.00	"Railroad Crossing" on blades. General.
Baltimore & Ohio System.....	Wood 7"x7"x16'-6"	4'	11"x6'-8"	26°30'	White	Black 9" high			"Railroad Crossing." on blades. "Look out for locomotive" on post. West Va.
Boston & Albany..............	Wood2-3"x8"x20'-0"	4'-6"	Diamond Fr. 12"x5'-3"	45°	White	Black 9" high	11.00	15.00	"Railroad Crossing" on one blade. "Look for the cars" on the other blade. Base to be creosoted.
Boston & Albany..............	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	10.00	14.00	"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. Paint lower 9' of post black. N.J.
Boston & Maine..............	66# Rail 20'-0"	5'	12"x8'-0"	30°	White	Black 9" high			"Railroad Crossing" on one blade. "Stop, look and listen" on the other blade.
Canadian Pacific.............	Wood 6"x7"x16'-6"	4'	8"x6'-5"	20°	White	Black 6" high	4.35		"Railway Crossing" on blades. Paint base with coal tar.
Canadian Pacific.............	Wood 6"x8"x16'-6"	4'	8"x7'-0"	20°	White	Black 6" high	5.00		"Railway Crossing" on one blade in English, the other blade in French. Prov. of Quebec.
Central New England..........	66# Rail 20'-0"	5'	12"x8'-0"	30°	White	Black 9" high	15.86	18.00	"Railroad Crossing" on one blade. "Stop, look and listen" on the other blade.
Chesapeake & Ohio...........	Wood 7"x7"x16'-6"	4'	8"x6'-5"	20°	White	Black 5" high			"Railway Crossing" on blades. Va. & Kentucky.
Chesapeake & Ohio...........	Wood 7"x7"x16'-6"	4'	8"x6'-5"	20°	White	Black 5" high			"Railway Crossing" on blades. "Look out for locomotive" on horizontal board.
Chesapeake & Ohio...........	Wood 7"x7"x17'-0"	4'	8"x6'-5"	30°	White	Black 5" high			"Railroad Crossing" on blades. "Danger" in red letters on horizontal board. Base of post to be dipped in tar. Ind.
Chestnut Ridge Railway......	Concr. 6"x6"x12'-0"	3'	6"x5'-0"	25°30'	White	Black 4" high	2.95	3.50	"Look out for trains" on blades.
Chicago, Indianapolis & Louisville........................	Wood 6"x6"x16'-0"	4'	12"x7'-0"	20°	White	Black 9" high	4.05	4.50	"Railroad Crossing" on blades. "Danger" in red letters on horizontal board. Base of post to be dipped in tar. Ind.
Chicago Great Western........	Wood 8"x8"x17'-6"	4'-6"	10"x7'-6"	25°	White	Black 6" high	10.00		"Railroad Crossing" on blades. "Stop" on post. Base of post tarred. Balance painted white.
Cleveland, Cincinnati, Chicago & St. Louis..................	Wood 7"x7"x16'-0"	4'	12"x7'-0"	30°	White	Black 10" high	5.00	7.00	"Railroad Crossing" on blades. Ohio & Ill.
Cleveland, Cincinnati, Chicago & St. Louis..................	Wood 7"x7"x16'-0"	4'	12"x7'-0"	30°	White	Black 10" high			"Railroad Crossing" on blades. "Danger" on horizontal board. Base painted with coal tar. Ind.

CROSSING SIGNS—Continued

Name of Railroad	Post	Depth in Ground	Blades	Angle from Horizontal	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription and other Information
Central Railroad of New Jersey	W.I.P. 0'x3"x14'-0"	4'	Rectangular 21"x4'-0"		Black	White 3" 6" high	$8.25	$15.25	"Look out for the locomotive." "Stop and listen" on board. Encase pipe in concrete for a depth of 4'.
Central Railroad of New Jersey	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high			"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. Creosote post below ground.
Chicago, Rock Island & Pacific	Wood 6"x6"x16'-6"	4'	11½"x6'-0"	30°	White	Black 8" high			"Railroad Crossing" on blades. Post painted red 4' above ground.
Cumberland Valley	W.I.P. 0'x3"x10'-9"	2'-6"	Ell. C. I. 18½"x4'-0"		White	Black 3" high			"Railroad Crossing" on blades. "Stop, look and listen" on plate. Post and back of sign painted black.
Delaware, Lackawanna & Western	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	7.35		"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. N. J.
Delaware, Lackawanna & Western	Wood 8"x8"x16'-0"	4'	12"x6'-8"	25°	White	Black 9" high	6.10		"Railroad Crossing" on blades. Lower 9' of post painted black. N. Y. & Pa.
Duluth & Iron Range	Round 0'-6"x16'-0"	4'	26"x8'-2"		White	Black 8" high			"Railroad Crossing" on blades. "Look out" on board.
El Paso & Southwestern	Wood 6"x8"x16'-0"	4'	12"x6'-0"	45°	White	Black 8" high			"Railroad Crossing" on blades. "Look out for the cars" on post.
Erie Railroad	Wood 7"x7"x19'-4"	4'-6"	12"x6'-6"	20°	White	Black 9" high			"Railroad Crossing" on blades. "Danger" on post. "Stop, listen, look out for the cars" on horizontal board.
Erie Railroad	Wood 7"x7"x19'-10"	4'-6"	12"x6'-6"	20°	White	Black 9" high			"Railroad Crossing" on blades. "Danger" on post. "Stop, listen, look out for the cars" on horizontal board.
Florida East Coast	Wood 6"x6"x16'-0"	3'	8"x6'-0"	20°	White	Black 5" high	2.30		"Railroad Crossing" on blades. "Look out for the cars" on horizontal board.
Great Northern	Round 0'-7"x16'-0"	4'	1-10"bl. 6'-0" 2 br.10"x4'-5"	45°	White	Black 8" high	2.74		"Railroad Crossing" on blades. Paint lower 5' of post black.
Hocking Valley	Wood 8"x8"x16'-0"	4'	7"x5'-6"	25°	White	Black 5" high	8.32		"Railroad Crossing" on blades. "Stop, look and listen" on horizontal board. Base of post painted black.
Houston & Texas Central	Wood 6"x8"x16'-0"	4'	10"x5'-0"	45°	White	Black 6" high			"Railroad Crossing" on blades. "Look out for the cars" on post. Paint portion in ground with coal tar.
Kansas Southwestern	Wood 6"x6"x16'-0"	4'	12"x6'-0"	30°	White	Black 8" high	4.22	5.50	"Railroad Crossing" on blades. "Safety first" on four sides of post. Paint portion in ground with coal tar.

CROSSING SIGNS—Continued

Name of Railroad	Post	Depth in Ground	Blades	Angle from Horizontal	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription and other Information
Lake Shore & Michigan Southern	Wood 6"x8"x15'-0"	4'	10"x5'-6"	25°	White	Black 9" high	$8.62	$10.62	"Railroad Crossing" on blades. "Danger" on horizontal board. Ind.
Lake Erie & Western	Wood 6"x8"x15'-0"	4'	12"x7'-0"	30°	White	Black 10" high	4.75	5.05	"Railroad Crossing" on blades. "Danger" in red letters on horizontal board.
Lehigh Valley Railroad	Wood 8"x8"x21'-0"	6'	1'-12"bl.10'-0" 2 br. 12"x6'-7"	45°	White	Black 9" high	9.62	10.34	"Railroad Crossing", "Look out for the cars" on blades. Post painted white. N.Y.
Lehigh Valley Railroad	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	8.25	8.70	"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. N. J.
Lehigh Valley Railroad	Wood 6"x6"x14'-9"	4'	Rect. Board 20"x5'-6"		White	Black 7" 9" high	5.70	6.00	"Railroad Crossing," on blade, "Stop, look and listen" on board. Pa.
Lehigh & New England	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	5.00	5.75	"Railroad Crossing" on one blade. "Stop, look and listen" on the other blade. Lower 9' of post painted black. Pa. & N. Y.
Lehigh & New England	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	5.60	5.75	"Railroad Crossing" on one blade. "Look out for locomotive" on the other blade. Lower 9' of post painted black. N. J.
Long Island Railroad	Wood 8"x8"x22'-0"	5'	Diam. Fr. 12"x6'-0"	45°	White	Black 10" high	13.50		"Railroad Crossing". "Look out for the cars" on board. "Stop" on post inside of frame. Paint base with tar.
Missouri Pacific	Wood 7"x7"x16'-0"	4'	11"x6'-0"	45°	White	Black 9" high	6.00	7.50	"Railroad Crossing" on blades. "Look out for the cars" on post.
Minneapolis & St. Louis	Round 0'-7"x16'-0"	4'	10"x6'-3"	30°	White	Black 8" high			"Railroad Crossing" on blades.
Nashville, Chattanooga & St. Louis	Wood 7"x7"x16'-6"	4'	8"x6'-5"	20°	White	Black 5" high			"Railroad Crossing" on blades. "Look out for the cars" on post.
New York Central	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	10.00	14.00	"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. Lower 9' of post painted black.
New York Central	Wood 2-3"x8"x20'-0"	4'-6"	Diam. Fr. 12"x5'-3"	45°	White	Black 9" high	11.00	15.00	"Railroad Crossing", "Look out for the cars" on blades. Base of post to be treated with preservative. N. Y.
Northern Pacific	Round 0'-6"x16'-0"	4'	8"x7'-0"	45°	White	Black 6" high	1.75	2.25	"Railroad Crossing" on blades.
Norfolk & Western	Wood 6"x6"x16'-0"	4'	8"x6'-6"	25°	White	Black 5" high			"Railroad Crossing" on blades. "Look out for the cars" on horizontal board. Md.
Norfolk & Western	Wood 6"x6"x16'-0"	4'	8"x6'-6"	25°	White	Black 5" high			"Railroad Crossing" on blades. "Look out for the locomotive" on horizontal board. Va., W. Va., Ohio, N. C.

CROSSING SIGNS—Continued

Name of Railroad	Post	Depth in Ground	Blades	Angle from Horizontal	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription and other Information
Norfolk & Western	Wood 6"x6"x16'-0"	4'	8"x6'-6"	25°	White	Black 5" high			"Railroad Crossing" on blades. Ky.
New York, New Haven & Hartford	66# Rail 20'-0"	5'	12"x8'-0"	30°	White	Black 9" high	$15.86	$18.00	"Railroad Crossing" on one blade. "Stop, look and listen" on the other blade.
Pennsylvania Railroad Co	W. I. 0'-3"x10'-9"	2'-6"	Ell. C. I. Pl. 18½"x4'-0"			Black 3" high			"Railroad Crossing," "Stop, look and listen" on plate. Post and back of sign painted black. Pa., Del., Va., Md., D. C.
Pennsylvania Railroad Co	W. I. 0'-3"x16'-0"	4'	C. I. Blades 12"x8'-0"	25°	White	Black 9" high			"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade. Post painted black to a ht. of 5'.
Pennsylvania Lines	Wood 7"x7"x16'-6"	4'	8"x6'-5"	20°30'	White	Mall. Iron Black 6" high	7.85	9.50	"Railroad Crossing" on blades. "Danger" on board.
Philadelphia & Reading	Wood 8"x8"x16'-0"	4'	12"x8'-0"	25°	White	Black 9" high	13.62	18.62	"Railroad Crossing" on one blade. "Look out for the locomotive" on the other blade.
Philadelphia & Reading	W. I. P. 0'-4"x14'-0"	3'-6" Con. 4'-6" Gr.	Ell. C. I. Pl. 19"x4'-0"		Black	3" White 6" high			"Look out for the locomotive," "Stop and listen" on board.
Pittsburgh, Chartiers & Youghiogheny	Wood 7"x7"x16'-6"	4'	8"x6'-5"	20°30'	White	Mall. Iron Black 6" high	7.85	9.50	"Railroad Crossing" on blades. "Danger" on board.
Richmond, Fredericksburg & Potomac	Wood 6"x8"x16'-0"	4'	8"x6'-0"	30°	White	Black 6" high	7.50	8.00	"Railroad Crossing" on blades. "Stop, look and listen" on post.
San Antonio & Aransas Pass	Wood 4"x6"x11'-0"	4'	10"x4'-3"	45°	White	Black 6" high	2.30	2.80	"Railroad Crossing" on blades.
Spokane, Portland & Seattle	Round 0'-8"x16'-0"	4'	9"x7'-0"	45°	White	Black 6" high			"Railroad Crossing" on blades. Base to be dipped in preservative. Upper 10' of post painted white.
Sunset Central Lines	Wood 6"x8"x16'-0"	4'	10"x5'-0"	45°	White	Black 6" high	4.25	6.00	"Railroad Crossing" on blades. "Look out for the cars" on post. Base of post to be dipped in coal tar.
St. Louis & San Francisco	Wood 6"x6"x16'-0"	4'	12"x6'-0"	30°	White	Black 8" high	3.17		"Railroad Crossing" on blades. "Safety first" on four sides of post. Paint portion below ground with tar.
Toledo & Ohio Central	Wood 6"x6"x16'-0"	4'	9"x6'-0"	30°	White	Black 6" high	3.25	4.75	"Railroad Crossing" on blades. "Warning" on post.
Wheeling & Lake Erie	Wood 6"x6"x14'-0"	4'	10"x6'-0"	30°	White	Black 8" high	1.42		"Railroad Crossing" on blades. Paint base of post with tar composition to a height of 2' above ground.

"(1) Please send blueprints of standards adopted or proposed, covering various kinds of metal, concrete or wood signs.

"(3) Cost of these signs in place.

"(4) Are there any laws in force in the States through which your lines pass governing kind of signs, wording on same, style of lettering, etc.? If so, please send copy of same.

"(5) Are there any decrees or rulings of State or Public Utility Commissions in the States through which your lines pass governing kind of signs, wording on same, style of lettering of same, etc.?

"(6) Please send copies of laws of States through which your lines pass regarding trespassers.

"(7) Please furnish any other information on this subject that may be of interest."

Sixty replies were received, nearly all of which contained some information useful to the Committee, either in the form of standard plans, rulings of Utilities Commissions, abstracts of laws relating to the maintenance of signs at public highway crossings, or laws relating to trespassing on railroad property.

A cursory examination of the information received suggested a natural sub-division of it into two classes: one applying to the general public, the other to the employes of railroad companies.

Owing to the scope of the subject coverd by the information at hand, the Committee considered it inexpedient at this time to take under consideration any signs except those in which the public is directly interested. On account of the great number and variety of these signs, it has confined its efforts to compiling information on the three signs in which the public is most vitally concerned, viz.: public and private road crossing and trespass signs.

The preceding tables have been prepared to show in condensed form detailed information as to the standard practice of the various railroads of the country. Table herewith shows general dimensions, size of letters, color of paint, cost and inscriptions of standard crossing signs used by 46 railroads from which replies have been received. Attention is called to the fact that of the above number 42 railroad companies are using wood signs consisting of a post about 16 ft. long, with two blades attached to the top of same at angles ranging from about 40 degrees to 90 degrees; 14 have added a horizontal board below the inclined blades bearing various inscriptions; 3 are using elliptical metal signs; 2 rectangular boards; 3 a square frame attached to the post diagonally, and 2 triangular frames. Of the entire number of standard plans furnished there is but one sign in which concrete was used, except in anchoring the posts in the ground.

The States of Indiana and New Jersey, through their Public Utilities Commissions, have prescribed forms of crossing signs that have been adopted as standard for use in those States. They have also provided that in the case of two or more railroads paralleling each other within certain distances the signs shall designate the number of railroads to be crossed. There are three or four different forms of signs in use in the State of New York which have been accepted by the Public Service Commission.

Herewith is submitted a diagram showing the various types of road crossing signs in use. While in only a few cases do any two roads agree as to details, in a general way the six types presented are fairly representative, and all in use could be grouped under the six classifications shown. The inscriptions, size of letters, detailed dimensions, etc., vary to suit local conditions and requirements, but in almost every case there is a close resemblance to some one of the typical signs exhibited on the diagram.

An attempt was made to secure copies of laws in every State affecting the size, design, etc., of signs to be placed at highway or street crossings. It was found difficult to secure them for each State, but we did succeed in getting them as in force in 32 States and Canada, as well as the decrees and rulings of the Public Utility or Railway Commissions of Connecticut, Indiana, New Jersey and Rhode Island. There are no laws in effect in regard to signs at highway crossings in Colorado, Louisiana, Nebraska or Oregon. These statutes and rulings will be found under Appendix 1, and it is hoped that the Committee will be able to supply those that are lacking for publication in the Proceedings. In order that quick conception may be obtained of the requirements of the laws in force, we present herewith a synopsis of same.

SYNOPSIS OF LAWS AND RULINGS OF PUBLIC UTILITIES COMMISSIONS RELATING TO ERECTION AND MAINTENANCE OF CROSSING SIGNS.

ALABAMA.—Railroads must erect warning signs at all public road crossings. Form of sign, wording of warning, and size of letters are not specified.

ARIZONA.—Railroads must erect warning signs at all public road crossings bearing the words. "RAILROAD CROSSING," "LOOK OUT FOR THE CARS," in letters at least 9 in. high; form of sign not specified.

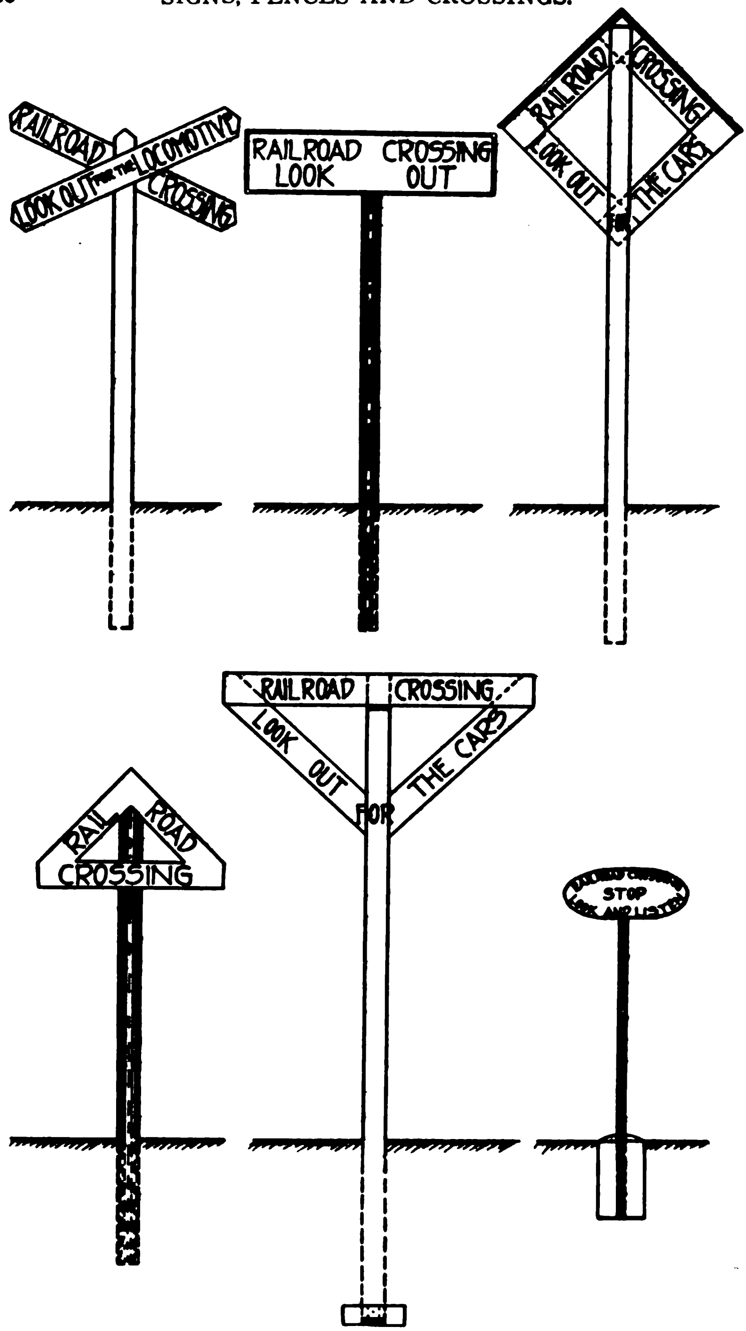
ARKANSAS.—Railroads must erect warning signs at all public road or street crossings bearing the words "RAILROAD CROSSING," "LOOK OUT FOR THE CARS WHILE BELL RINGS OR WHISTLE SOUNDS," in letters at least 9 in. high. Does not apply to city or village streets unless required by local authorities.

CANADA.—Railroads are required to erect sign boards at all highway crossings containing the words "RAILROAD CROSSING" in letters at least 6 in. high. In the Province of Quebec these words must be printed in both the English and French languages.

COLORADO.—In Colorado there are no statutes or rulings of the Railroad Commission governing signs at crossings affecting the wording or size of lettering on same.

CONNECTICUT.—Warning boards approved by the Commissioners must be erected at all grade crossings where there are no gates. Form of sign, wording and size of letters not specified.

DELAWARE.—Railroads are required to erect sign boards at all highway crossings bearing the inscription "RAILROAD CROSSING" in letters at least 5 in. high.



TYPICAL CROSSING SIGNS.

FLORIDA.—Sign boards bearing the inscription "LOOK OUT FOR THE CARS" must be maintained at all public highway crossings. Bell must be rung before crossing streets of cities and speed is restricted to 4 miles per hour.

ILLINOIS.—Sign boards bearing the words "RAILROAD CROSSING" or "LOOK OUT FOR THE CARS," in letters at least 9 in. high, must be maintained at all public road crossings except in cities or towns where crossings are controlled by local authorities.

INDIANA.—Sign boards bearing the words "RAILROAD CROSSING," in letters at least 9 in. high, must be erected at all public road crossings. A board containing the word "DANGER," in red or black letters, must be attached to the post at least 7 ft. above the ground. Where two railroads parallel each other within 100 ft., the word "TWO" shall appear on the post.

IOWA.—Warning boards must be provided at all public road crossings. Form of sign, inscription and size of letters not specified.

KANSAS.—Sign boards containing the words "LOOK OUT FOR THE CARS" must be maintained at all public road or street crossings, except in cities and towns where crossings are controlled by local authorities; form of sign or size of letters not specified.

KENTUCKY.—Sign boards bearing the inscription "RAILROAD CROSSING," in letters at least 5 in. high, must be maintained at all public highway crossings, except in cities and towns where it is optional with local authorities.

LOUISIANA.—There are no statutes in force in Louisiana prescribing form of sign, inscription or size of letters.

MAINE.—Sign boards bearing the words "RAILROAD CROSSING" must be maintained at all public road crossings. No form of sign or size of letters specified.

MARYLAND.—Statute requires railroads to erect signs at all public road crossings, but form of sign, inscription and size of letters are not specified.

MASSACHUSETTS.—Statute requires signs with words "RAILROAD CROSSING," "LOOK OUT FOR THE ENGINE," in letters 9 in. high at each highway or townway, unless substitute has approval of Board of Railroad Commissioners. Form of sign not specified.

MICHIGAN.—Sign boards at each public road or street crossing must contain the words "RAILROAD CROSSING" in letters not less than 12 in. high, except in cities or towns, unless other form is prescribed by local authorities or the railroad commissioner.

MINNESOTA.—Statute requires signs at all public road crossings, but no form of sign, size of letters or wording suggested.

MISSISSIPPI.—Sign boards bearing inscription "LOOK OUT FOR THE LOCOMOTIVE" or "RAILROAD CROSSING" must be maintained at all highway crossings. No style of sign or size of letters specified.

MISSOURI.—Sign boards bearing words "RAILROAD CROSSING" in letters at least 9 in. high must be maintained at all public road or street crossings where gates are not provided.

NEBRASKA.—There is no statute in Nebraska covering style of sign, inscription or size of letters on same.

NEW JERSEY.—Statute requires sign boards bearing words "LOOK OUT FOR THE LOCOMOTIVE" in letters at least 9 in. high at all

public road or street crossings except in cities and towns where style of sign is optional with local authorities.

The Public Utilities Commissioners have recently prescribed a form of crossing sign which bears the inscription "RAILROAD CROSSING," "LOOK OUT FOR THE LOCOMOTIVE," and where two railroads parallel each other within 400 ft. the words "TWO CROSSINGS" shall appear on sign.

Where a crossing sign cannot be clearly seen on account of obstructions at a distance of 150 ft. from a crossing, an additional sign to read "RAILROAD CROSSING, 150 FEET," shall be erected at a distance of 150 ft. from the crossing.

New York.—Sign boards are required by statute. Style and inscription left to Public Service Commission. Inscriptions in use: "RAILROAD CROSSING," "LOOK OUT FOR THE CARS," "DANGER RAILROAD CROSSING," "RAILROAD CROSSING," "LOOK OUT FOR THE CARS," "STOP."

North Dakota.—Statute requires signs having white background with black letters at least 8 in. high at all crossings. No form of sign or wording specified.

Ohio.—Sign boards required at all public road crossings, but no style of sign, wording or size of letters specified.

Oklahoma.—Signs required by statute at all public road crossings bearing inscription "RAILROAD CROSSING," "LOOK OUT FOR THE CARS," in black letters at least 8 in. high, on white background, on posts 15 ft. high.

Oregon.—There are no laws in force governing the kind of signs, wording on same and style of lettering, the matter being under the jurisdiction of the Railroad Commissioners.

Pennsylvania.—Has no statutory provision as to crossing signs, cases of proper precaution lays down the rule that due care must be taken to prevent accidents, and proper precautions are construed to include signs at crossings.

Rhode Island.—Requires sign boards at all highway crossings bearing the words "Railroad Crossing," "Stop, Look and Listen," in letters at least 9 in. high under direction of the Railroad Commissioners.

South Dakota.—Railroads must erect and maintain signs containing words "Railroad Crossing," "Look Out for the Cars," in letters at least 8 in. high. Form not specified.

Tennessee.—Overseers of public roads are required to provide signs marked "Look Out for the Cars When You Hear the Whistle or Bell."

Texas.—Signs are required by statute, but no wording, size of letters or form of sign specified.

Virginia.—Statute requires erection and maintenance of signs with "Railroad Crossing" inscribed thereon in letters at least 5 in. high.

West Virginia.—Sign boards are required by statute bearing the inscription "Railroad Crossing," "Look Out for the Locomotive." No style of sign or size of letters specified.

Washington.—Sign boards must be erected at all highway crossings, the form of which is to be prescribed by the Public Service Commission.

Wisconsin.—Sign boards bearing the inscription "Look Out for the Cars" must be erected and maintained at all public highway crossings. No form or size of letters specified.

It may be of interest to scan quickly the inscriptions and size of letters required by each State, as with two exceptions they are the principal features of the laws and rulings; we, therefore, submit them below:

STATUTORY INSCRIPTIONS, ETC., ON CROSSING SIGNS.

State.	Inscription.	Size of Letters.
Alabama		
Arkansas	Railroad crossing; look out for the cars	9 in.
Arkansas	Railroad crossing; look out for the cars while bell rings or whistle sounds	9 in.
Canada	Railroad crossing	6 in.
Colorado		
Connecticut		
Delaware	Railroad crossing	5 in.
Florida	Look out for the cars	9 in.
Illinois	Railroad crossing, or, look out for the cars	9 in.
Indiana	Railroad crossing—danger	9 in.
Iowa		
Kansas	Look out for the cars	5 in.
Kentucky	Railroad crossing	5 in.
Louisiana		
Maine	Railroad crossing	
Maryland		
Massachusetts	Railroad crossing; look out for the engine.	9 in.
Michigan	Railroad crossing	12 in.
Minnesota		
Mississippi	Railroad crossing, or, look out for the locomotive	
Missouri	Railroad crossing	9 in.
Nebraska		
New Jersey	Look out for the locomotive	9 in.
New York	Railroad crossing, look out for the cars	
North Dakota		
Ohio		
Oklahoma	Railroad crossing, look out for the cars	8 in.
Oregon		
Pennsylvania		
Rhode Island	Railroad crossing, stop, look and listen	9 in.
South Dakota	Railroad crossing, look out for the cars	8 in.
Tennessee	Look out for the cars when you hear the whistle or bell	
Texas		
Virginia	Railroad crossing	5 in.
Washington		
West Virginia	Railroad crossing, look out for the locomotive	
Wisconsin	Look out for the cars	

The Committee finds that only three of the roads that submitted plans use standard road crossing signs made of metal, with metal posts; the balance uniformly use wood. One has used a sign and post made of concrete, but it does not commend itself. Another uses a wooden sign with a concrete post, but this is in an experimental way, and has not yet been tested out for merit.

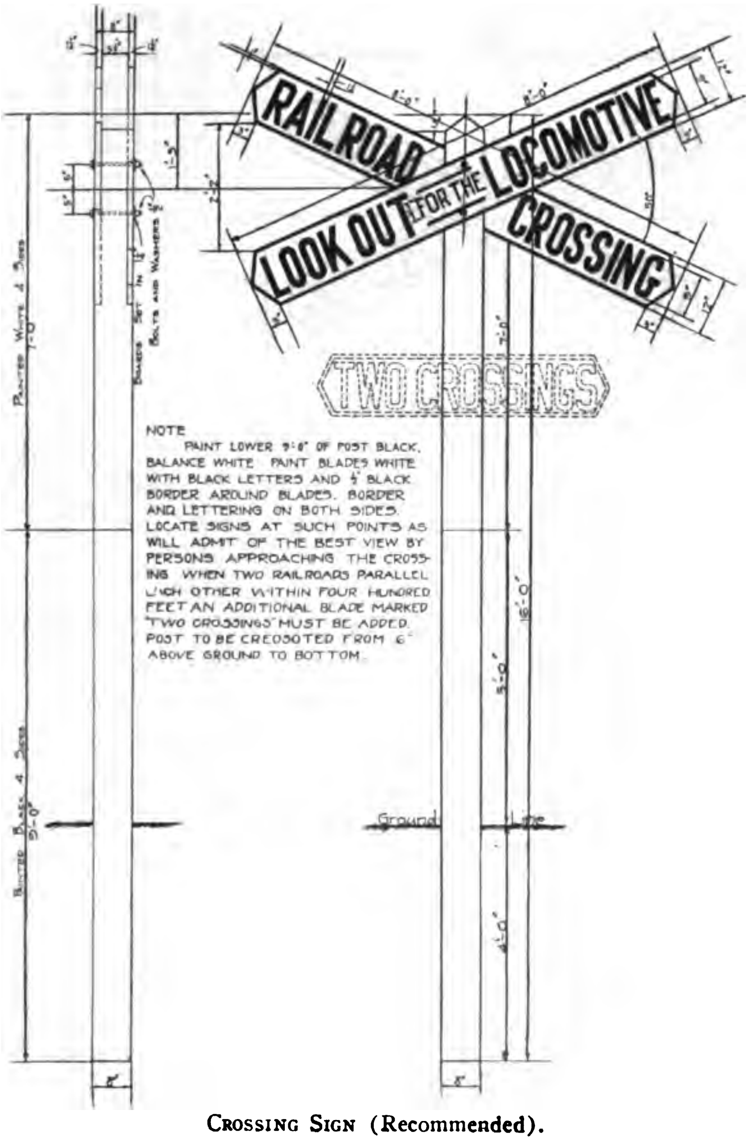
With very few exceptions the various roads have some form of sign made of two wooden blades placed in a diagonal form to represent a crossing, the angles between blades varying from 40 degrees to 90 degrees. There is no doubt but that this form of sign is most suggestive, and is indicative of its purpose and intention, exclusive of the wording thereon. An illiterate person could scarcely be ignorant of its meaning, particularly since it is in such general use. This argues strongly for its recommendation by our Association. Such a form of sign does not lend itself readily to the use of any other than a wooden post. Concrete may be used, but the Committee is not prepared to even advise it, as experience with concrete posts of this character has been limited, and it is of the belief that such a post would be easily broken.

The most frequent wording on the signs is "RAILWAY CROSSING" or "RAILROAD CROSSING." Some States, however, by law or Public Utility Commission ruling, require different or additional language. Inevitably the wording will have to conform with any special requirements. The Committee does not feel warranted in specifying the use of any particular kind of timber, as that in most general use differs in various parts of the country. Roads will unquestionably, and properly so, use the timber that is native to their locality, and which has the longest life, or which can be the most readily secured. The height of sign above the ground will have to be varied in some places to meet certain local conditions.

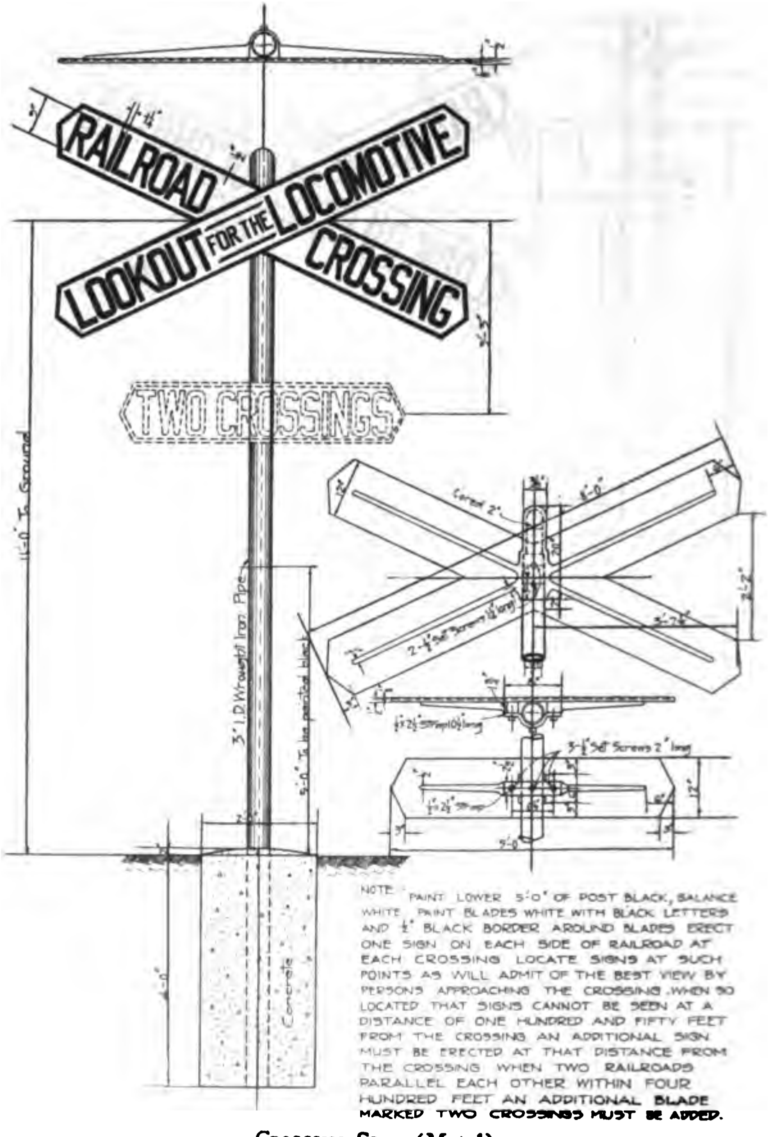
The objects to be achieved in the selection of a proper form of road crossing sign are reasonable cheapness in first cost, economy in maintenance, which includes durability, and the merit of serving the purpose for which it is placed, that is, to give proper and ample warning of the existence of a railroad crossing.

The Committee, therefore, presents a design of sign which, in its opinion, most adequately meets these conditions. It should be made with wooden blades 12 in. wide and 8 ft. long, with mitred ends placed in a diagonal manner with an angle of 50 degrees between blades on an 8-in. by 8-in. by 16-ft. wooden post. The post should stand 4 ft. in the ground, and be creosoted from bottom to 6 in. above ground line. The lower 9 ft. of post should be painted black, and the balance white. The blades should be painted white with black letters, and ½-in. black border around blades. Border and lettering should be on both sides. Letters should be Egyptian style, 9 in. high, with the exception of connecting terms, as "for the" in the recommended sign, which should be 4 in. high.

One very large trunk line has adopted a modified form of this sign made of cast-iron on wrought-iron pipe post. The Committee presents as information a plan of this sign. It has not felt warranted in recommending it for the reasons that it is quite expensive, it has not been tried out for but a short period of time; hence, any disadvantages in its use may not have developed. The blades are a single casting and hence very heavy and liable to breakage in handling. In brief, it is yet but an un-



Crossing Sign (Recommended).



Crossing Sign (Metal).

TRESPASS SIGNS

Name of Railroad	Post	Depth in Ground	Board	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription
Atchison, Topeka & Santa Fe......	Wood 4"x4"x9'-0".......	3'	Boiler Pl. 18"x30"	White	2 " high Black 3 " high	$2.53	$3.00	Danger. Keep off this bridge. The A. T. & S. F. Ry. Co.
Atchison, Topeka & Santa Fe......	Wood 4"x4"x9'-0".......	3'	Boiler Pl. 18"x30"	White	1½" Black 2 " high	1.44	1.75	This is private property. Trespassers are warned to keep off. The A. T. & S. F. Ry. Co.
Atchison, Topeka & Santa Fe......	Wood 4"x4"x9'-0".......	3'	Boiler Pl. 18"x30"	White	2" Black 2½" high	1.05	1.50	Notice—This is not a public highway. It is the property of the A. T. & S. F. Ry. Co.
Baltimore & Ohio System.........	W. I. P. 0'-3"x8'-0"....	3'	C. I. Plate 10½"x27½"	White	Black	2.55	3.55	Warning. Trespassing upon railroad property forbidden.
Canadian Pacific..................	Wood 4½"x4½"x9'-9".....	3'-6"	18½"x2'-10"	Black	2" White 2½" high	2.30		Caution. Do not walk nor trespass on the railway.
Chicago Great Western............	W. I. P. 0'-3"x10'-0"...	3'-6"	18"x2'-9"	White	2½" Black 3 " high	4.50		Railroad property. Danger. Keep off.
Chicago, Rock Island & Pacific....	Wood 6"x6"x12'-0"......	4'	18"x4'-0"	White	Black 4 " high			C. R. I. & P. Ry. Private property. Keep off.
Chesapeake & Ohio...............	W. I. P. 0'-6"x10'-0"...	2'	18"x3'-4"	Black	3 " White 4 " high			Caution. Keep off the track.
Chesapeake & Ohio...............	W. I. P. 0'-6"x10'-0"...	2'	18"x3'-4"	Black	3 " White 4 " high			Caution. Keep off the bridge.
Central Railroad of New Jersey....	W. I. P. 0'-2"x12'-3"....	3'-6"	C. I. Plate 18"x2'-6"	Black	2 " White 2½" high	4.10	7.10	Private property. Trespassing forbidden under penalty of law.
Central Railroad of New Jersey....	W. I. P. 0'-2"x12'-3"...	3'-6"	C. I. Plate 18"x2'-6"	Black	2 " White 2½" high	4.10	7.10	Danger. Do not trespass on the railroad.
Central Railroad of New Jersey....	W. I. P. 0'-2"x12'-3"...	3'-6"	C. I. Plate 18"x2'-6"	Black	2 " White 2½" high	4.10	7.10	Danger. Do not trespass on this bridge.
Delaware, Lackawanna & Western.	Wood 3"x4"x8'-0"......	3'	12"x2'-9"	White	Black 3½" high	2.10		No trespassing.
Duluth & Iron Range.............	Cedar 0'-6"x12'-0".....	3'	36"x5'-0"	White	3½" Black 9 " high			Danger. Keep off the track. Any person walking upon the railroad tracks is a trespasser and assumes all risk.
Florida East Coast...............	Wood 2"x4"x7'-6"......	2'	12"x1'-6"	White	Black	.90		Warning. All persons are forbidden under penalty of law from walking on this track or trespassing on the property of this company. F. E. C. Ry. Co.
Great Northern..................	Cedar 0'-7"x10'-0"....	3'	28 x5'-0"	White	Black 4 " high	1.12		Property of the Great Northern Railway Co. Trespassing forbidden. Danger.
Houston & Texas Central..........	Wood 5½"x5½"x12'-0"..	3'-2'	18"x2'-6"	White	Black 2½" high	4.00	5.00	Private property. Permission to pass over revocable at any time.

TRESPASS SIGNS—Continued

Name of Railroad	Post	Depth in Ground	Board	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription
Lake Shore & Michigan Southern..	Scrap Rail 14'-0"......	4'	Boiler Pl. 16"x2'-3"	White	1¾" Black 2" high	3.75	4.75	Notice. Railroad grounds. No thoroughfare. No trespassing allowed. Dangerous.
Lehigh Valley Railroad...........	Wood 4"x6"x13'-0"......	3'	24"x3'-0"	White	2½" Black 3¼ high	2.25	2.50	Railroad property. No thoroughfare. Walking here is forbidden.
Lehigh Valley Railroad...........	Wood 4"x6"x13'-0"......	3'	24"x3'-0"	White	1½" Black 2" high	2.23	3.42	Notice.—This land is private property and all persons are hereby warned from trespassing thereon under penalty of the law as provided in the Act of the Assembly passed April 14, 1905. Lehigh Valley R. R.
Lehigh Valley Railroad...........	Wood 4"x6"x13'-0"......	3'	18"x4'-6"	White	2" Black 3" high	2.00	2.80	No trespassing. Private property of the Lehigh Valley R. R. Not a public thoroughfare.
Lehigh & New England...........	W. I. P. 0'-2"x16'-0"...	4'	18"x3'-0"	Black	2" White 3½" high	5.34	6.37	Danger. Trespassing on railroad property positively forbidden.
Long Island Railroad.............	Wood 2¾"x5¾"x12'-0". ..	4'	Ell. C.I.Pl. 16"x2'-1"	White	2" Black 3" high	3.41		Danger. No trespassing.
Missouri Pacific.................	Wood 4"x4"x7'-0"......	2'-6"	16"x1'-10"	White	1" Black 3½" high	1.21	1.46	Warning. Trespassing on the tracks and right-of-way is positively forbidden.
Minneapolis & St. Louis...........	Cedar 0'-6"x10'-0".....	2'-6"	11½"x4'-0"	White	Black 2½ high			Not a public highway. Do not trespass.
Nashville, Chattanooga & St. Louis	Rail..................		16"x2'-1"	White	1½" Black 1¾" high			Notice. All persons are warned not to trespass on these grounds or tracks.
Nashville, Chattanooga & St. Louis	Rail..................		18"x2'-1"	White	1½" Black 1¾" high			All persons are warned not to trespass on this bridge.
Norfolk & Western................	Wood 4½x4½x11'-6".....	3'	18"x3'-0"	White	3" Black 3½" high			Do not walk nor trespass on the bridge.
Norfolk & Western................	Wood 4½"x4½"x11'-6"...	3'	18"x3'-0"	White	3" Black 3½" high			Danger. All persons except employees of the N. & W. Ry. Co., are forbidden to go on these premises.
Norfolk & Western................	Rail 56 10 to 12'-0"...	3'	C. I. Plate 18"x3'-0"	White	Black 2½" high			Do not walk nor trespass on the bridge.
New York, New Haven & Hartford	Wood 4"x4"x11'-6"......	4'	24"x3'-0"	Black	1½" White 3" high	2.80		Danger. Walking on the track or other trespassing is forbidden.
New York, New Haven & Hartford	Wood 4"x4"x11'-6".....	4'	24"x3'-0"	Black	3½" White 4" high	2.80		Private way. No thoroughfare. Use by the public prohibited.

TRESPASS SIGNS—Continued

Name of Railroad	Post	Depth in Ground	Board	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription
Pennsylvania Railroad Co.	W. I. P. 0'-2½"x10'-0"	2'	C. I. Plate 21"x2'-10"	White	Black 2" high			Not a public crossing. All persons are warned not to trespass.
Pennsylvania Railroad Co.	W. I. P. 0'-2½"x10-0"	2'	C. I. Plate 18"x2'-10"	White	Black 2½" high			Caution. Do not walk nor trespass on the railroad.
Pennsylvania Railroad Co.	W. I. P. 0'-2½"x10'-0"	2'	C. I. Plate 18"x2'-10"	White	Black 2½" high			Do not walk nor trespass on this bridge.
Pennsylvania Lines	W. I. P. 0'-2½"x10'-0"	2'	C. I. Plate 21"x2'-10"	White	Black 2" high	$4.76	$6.47	Not a public crossing. All persons are warned not to trespass.
Pennsylvania Lines	W. I. P. 0'-2½"x10'-0"	2'	C. I. Plate 18"x2'-10"	White	Black 2½" high	4.76	6.47	Caution. Do not walk nor trespass on the railroad.
Philadelphia & Reading	W. I. P. 0'-2"x12'-3"	3'-6"	C. I. Plate 18"x2'-6"	Black	White 2½" high	1.86	6.86	Private property. Trespassing forbidden under penalty of law.
Philadelphia & Reading	W. I. P. 0'-2"x12'-3"	3'-6"	18"x2'-6"	Black	White 2½" high			Danger. Do not trespass on the railroad.
Philadelphia & Reading	W. I. P. 0'-2"x12'-3"	3'-6"	18"x2'-6"	Black	White 2½" high			Do not trespass on the bridge. Danger.
Spokane, Portland & Seattle	Cedar 0'-8"x10'-0"	3'	22"x3'-6"	White	Black 4" high	2.00	3.00	Property of Spokane, Portland & Seattle Ry. No trespassing.
Sunset Central Lines	Wood 5½"x5½"x12'-0"	3'-2"	18"x2'-6"	White	Black 2½" high	2.85	4.35	Private property. Permission to pass over revocable at any time.
St. Louis & San Francisco	Wood 6"x6"x12'-0"	4'	18"x4'-0"	White	Black 4" high	4.30		St. Louis & San Francisco R. R. Private property. Keep off.
Wheeling & Lake Erie	Boiler Tube 12'-0"	3'-4"	Steel Plate 18"x2'-10"	White	Black 2½" high			Railroad property. No trespassing. For country use.
Wheeling & Lake Erie	Wood 4"x4"x12'-8"	4'	18"x2'-10"	White	Black 2½" high	.84		Railroad property. No trespassing. For city use.
Wheeling & Lake Erie	Wood 4"x4"x12'-8"	4'	18"x2'-6"	White	Black 2½" high	1.63		Danger. Keep off this bridge.

PRIVATE ROAD CROSSING SIGNS

Name of Railroad	Post	Depth in Ground	Board	Back Ground	Letters	Cost F.O.B.	Cost in Place	Inscription
Central Railroad of New Jersey	W. I. P. 0'-2"x12'-3"	3'-6"	C. I. Plate 12"x2'-6"	Black	White 2½" high	$2.95	$5.95	Private crossing.
Florida East Coast	Wood 6"x6"x12'-0"	3'	14"x4'-0"	White	Black 5" high	.90		Private crossing. Persons using this crossing do so at their own risk and must not rely upon signals from the train. F. E. C. Ry. Co.
Lehigh Valley Railroad	Boiler Tube 0'-2"x9'-0"	3'	W. I. Plate 13"x2'-2"	White	Black 4" high	1.32	1.68	Private crossing.
Lehigh & New England	Wood 4"x4"x12'-0"	3'-6"	16"x2'-10"	White	Black 4" high	1.50	2.00	Private crossing.
New York, New Haven & Hartford	Wood 4"x4"x11'-6"	4'	24"x3'-0"	Black	White 4" high	2.30	2.80	Private crossing. Dangerous. Look out for trains.
Philadelphia & Reading	W. I. P. 0'-2"x12'-3"	3'-6"	12"x2'-6"	Black	White 2½" high	1.81	6.81	Private crossing.

tried experiement for such a design of sign. It is but fair to say, however, that the testimony up to date is to the effect that it has given entire satisfaction. It may be possible, therefore, that at some future time the Committee may be able to recommend its substitution for the wooden sign of same general dimensions presented in the foregoing.

The Committee also made an investigation of the various kinds of trespass signs in use by the railroads. Replies were received from 28 roads, submitting 46 forms of signs, differing in style, phraseology, etc. We are presenting below a table giving a brief description of the sign in use on each road, as well as prices delivered f. o. b. line of road, and cost in place to the extent that such data was available.

We are also furnishing a description of the private road crossing signs in use on six of the roads, but the information on these was so meagre that the Committee thought they could hardly be in very general use, and, therefore, concluded to ignore this particular form of sign until further investigation was made.

Inquiry was also made as to the laws in force in the various states and Canada, relating to the subject of trespassing. We obtained the text of such laws for 28 states and Canada. We are submitting them under Appendix 2, and hope to secure copies of those in force in the remaining states for publication in the annual proceedings. In order that the substance of these laws may be quickly referred to, we are presenting a brief synopsis of them herewith.

SYNOPSIS OF LAWS RELATING TO TRESPASSING ON RAILROAD AND PRIVATE PROPERTY.

ARKANSAS.—No laws relative to trespassing on tracks or right-of-way. Railroads liable for killing trespassers, if negligence is shown.

CANADA.—Law very explicit and complete for various classes of trespassers.

CALIFORNIA.—Has law prohibiting use of right-of-way by vehicles, but is weak on common trespassers.

COLORADO.—There is no statute with reference to trespassers upon railroad property. There are certain statutes which designate as crimes the turning or operating of switches, and the use of railroad tracks by use of a railway bicycle, push car, hand car, slide, or other similar vehicles or device, excepting such as are provided by said railroad company to be used for such purpose; and also providing for the punishment of parties guilty of the removal of waste or packing, or brass or brasses, etc., or throwing stones at the train.

CONNECTICUT.—Law applies particularly to stealing rides and malicious trespass; not to common trespass.

DELAWARE.—Law applies to trespass on private land and railroad cars; not explicit on trespassing on railroad tracks or right-of-way.

FLORIDA.—General trespass law, but no specific reference to trespass on tracks or right-of-way.

IDAHO.—Applies to disorder on trains and refusal to pay fare; does not cover trespass on track or right-of-way.

INDIANA.—General trespass law covering trespass on private property and would apply to railroad tracks and property; also law covering interference with brakes and signals.

ILLINOIS.—Has no general statute prohibiting trespassing on railroads, but has rather stringent regulations on malicious trespass and stealing rides.

IOWA.—Malicious trespass fully covered, but no law relative to trespass on railroad property.

KANSAS.—Has no statute specifically covering trespassing on right-of-way, but has very complete law covering malicious trespassing.

KENTUCKY.—Has no statutory regulation on trespassing, but Court of Appeals has announced that the company is only responsible for injury to a trespasser which could have been prevented by ordinary care.

LOUISIANA.—Has statute on stealing rides, but none relative to trespassing on railroad tracks or property.

MAINE.—Trespass statute fully covers all forms of trespass on railroad property or tracks, and releases company of liability if law is properly posted.

MARYLAND.—Statute covers stealing rides on trains, but is silent on common trespass.

MASSACHUSETTS.—Trespass statute covers trespass on tracks or right-of-way. No provision covering malicious trespass.

MICHIGAN.—Statutes do not cover trespassing on railroad tracks or property, nor malicious trespass. Not broad enough to cover trespass on railroad property.

MINNESOTA.—Statutes cover both malicious and common trespass on railroad property.

MISSOURI.—Law covers trespass on tracks of railroad companies; but does not include malicious trespassing.

MONTANA.—Statute covers matter of disorder or refusal to pay fare, use of force to expel, etc., but does not cover trespass on tracks or right-of-way.

NEBRASKA.—General law covering malicious trespass, but scarcely applicable to railroad property.

NEW YORK.—Covers trespassing on railroad tracks, but not malicious trespassing.

OHIO.—Statute covers trespassing by team on tracks and right-of-way, stealing of rides and malicious trespass, but not walking on tracks.

OKLAHOMA.—Covers malicious trespass and preservation of order on railroad property.

OREGON.—Covers malicious trespass, unauthorized riding of equipment and trespassing on tracks.

PENNSYLVANIA.—Statute covers malicious trespass and unauthorized riding on trains. Trespass signs must be worded as follows: "Notice.—This is private property and all persons are hereby warned from trespassing thereon under penalty of the law, as provided in the Act of Assembly passed April 14th, 1905."

RHODE ISLAND.—Statute covers trespass on right-of-way; no provision for malicious trespassing.

SOUTH DAKOTA.—Malicious trespass only. No statute covering common trespass on tracks or right-of-way.

TENNESSEE.—Specified precautions to be taken to prevent accidents on railroad to trespassers.

UTAH.—Statute deals with unauthorized riding of equipment.

VIRGINIA.—Covers malicious trespass, walking on tracks, stealing rides, disorderly conduct, etc.

WEST VIRGINIA.—Covers trespassing on trains and disorderly conduct.

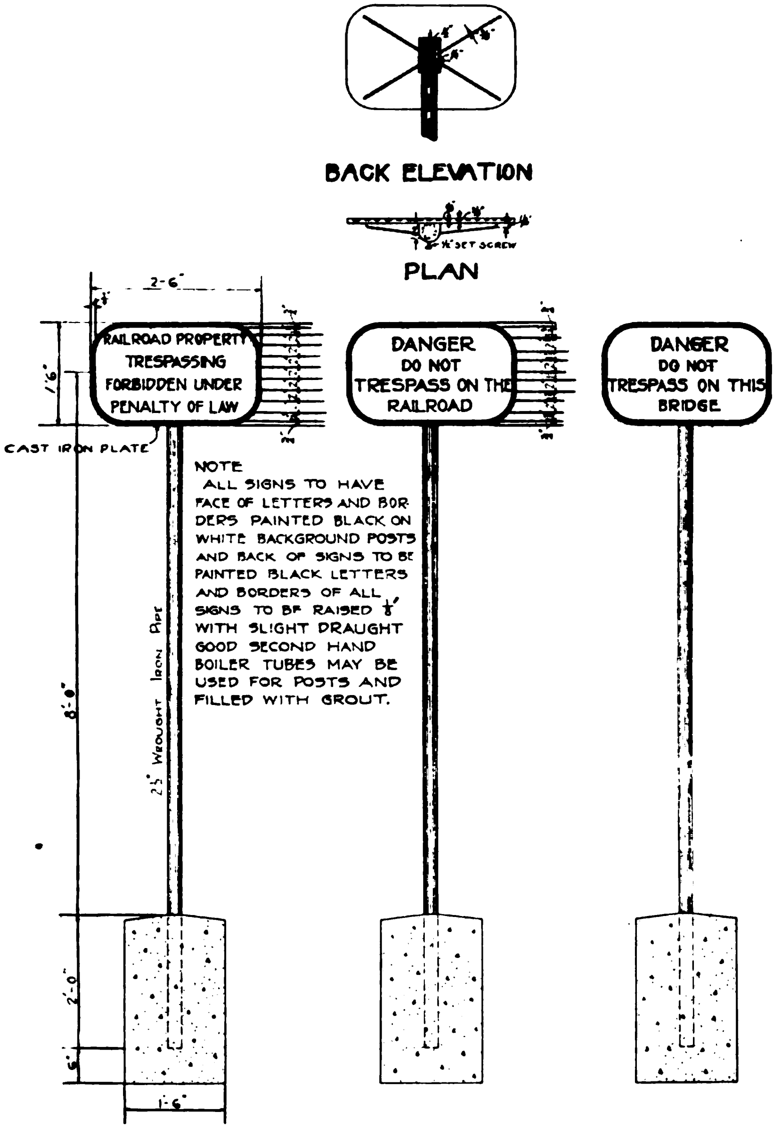
WASHINGTON.—Statute covers trespassing on railroad right-of-way and malicious destruction of railroad property.

It will be observed that there are no statutory regulations with regard to the form of sign, character of wording to be employed, etc., except in the State of Pennsylvania, which specifies that the sign should read "Notice.—This is private property and all persons are hereby warned from trespassing thereon under penalty of the law as provided in the Act of Assembly passed April 14th, 1905."

The signs of this character in most general use are made of wood, with wooden post, but there seems to be a greater tendency to use cast-iron or steel plate with wrought-iron post than in the case of the crossing signs. We also find that a number of roads that are now using wood are considering the feasibility of going to a metal sign. The size of signs, wording on same, character of lettering, etc., varies with each road and scarcely any two of them are alike. The only similarity exists in the cases of those roads which have adopted metal signs. The cost of metal signs is but slightly in excess of the cost of many styles of wooden signs. It is the experience of those roads which formerly used the wooden signs and later adopted those of metal, that the metal sign, while slightly more expensive in first cost, is more durable, and can be more easily maintained, including repainting.

The Committee, therefore, presents a form of sign which would seem to most nearly conform to what is required in the way of reasonable first cost, durability, neatness and legibility. The wording on same might conform to the judgment of the management of each particular road, where statutory regulations do not provide for the form of wording.

These signs should be made of cast-iron ¼-in. in thickness, borders to be raised ⅛-in., with slight draught; they should be 1 ft. 6 in. deep by 2 ft. 6 in. wide, with ⅜-in. diagonal cast ribs on back for stiffness; all signs to have face of letters and borders painted black on white background; posts and back of signs to be painted black, letters to be raised ⅛-in. with slight draught; 2½-in. wrought-iron pipe, or good second-hand boiler tubes filled with grout to be used for posts. When concrete or stone foundations are not used, the pipe is to be planted 3 ft. 6 in. deep in the ground and a 1-in. diameter gas pipe about 18 in. long should be run through the pipe post about 1 ft. below ground line to keep it from turning. The wording indicated on typical signs presented, "RAILROAD PROPERTY—TRESPASSING FORBIDDEN UNDER PENALTY OF LAW," or "DANGER—DO NOT TRESPASS ON THE RAILROAD," is suggested.



TRESPASS SIGNS (Recommended).

(3) CONCRETE AND METAL AS COMPARED WITH WOOD FOR FENCE POSTS.

A meeting of the Sub-Committee was held in Chicago on September 19, 1913, at which were present Maro Johnson, Chairman; Arthur Crumpton, H. E. Billman, J. T. Frame.

The subject of concrete posts was taken up at the stage that the Committee had reached at the conclusion of the previous year, and it was determined to undertake to have exhaustive tests made to ascertain the actual strength of the various kinds of concrete posts under different conditions. Sample posts were to be secured from the different railroads using them. Arrangements have been made to conduct the tests, and they will be supervised and financed by the Universal Portland Cement Company, and made at the Lewis Institute of Chicago, to both of which the Committee is indebted for the manifestation of interest. The results of these tests will not be in shape for presentation for some time yet, and the Committee hopes to submit interesting data on this subject next year.

CONCLUSIONS.

Your Committee recommends:

(1) The adoption of the specifications and plan for highway crossing signs as shown on page 873.

(2) The adoption of the specifications and plan for public trespass signs as shown on page 881.

Respectfully submitted,

COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

Appendix A.

LAWS RELATIVE TO ERECTION OF CROSSING SIGNS.

In response to inquiry No. 4, "Laws relative to erection of crossing signs," abstracts were received from thirty-three States, as follows:

ALABAMA.—Code of 1907, Section 5475.—Every railroad company must erect, at all points where its road crosses any public road, at a sufficient elevation to admit of the free passage of vehicles of every kind, a sign, with large and distinct letters placed thereon, to give notice of the proximity of the railroad and warn persons of the necessity of looking out for the cars.

ARKANSAS.—Kirby's Digest 1904, Section 6596.—Every railroad corporation in this State shall cause boards to be placed, well supported by posts or otherwise, and constantly maintained, across each public road or street where the same is crossed by the railroad on the same level. Said boards shall be elevated, so as not to obstruct travel, and to be easily seen by travelers, and on each side of said boards shall be painted, in capital letters of at least the size of 9 in. each, the words "RAILROAD CROSSING"—"LOOK OUT FOR THE CARS WHILE THE BELL RINGS OR THE WHISTLE SOUNDS," but this section shall not apply to streets in cities or villages, unless the corporation be required to put up such boards by the officer having charge of such streets.

ARIZONA.—And every such corporation shall also cause boards to be placed, well supported by posts or otherwise, and constantly maintained, across each public road or street where the same is crossed by railroad; said boards shall be elevated so as not to obstruct the travel, and to be easily sene by travelers, and on each side of said boards shall be painted in capital letters of at least the size of 9 in. each, the words, "RAILROAD CROSSING,"—"LOOK OUT FOR THE CARS." If such corporation fail to construct and maintain said crossings or to put up boards as above provided, then the overseers, municipal authorities or parties having legal control or charge of said roads or streets, shall notify such corporations of the necessity for the construction thereof, which notice shall be in writing, and shall be served by delivering a copy of the same to the agent of the company most convenient to the crossing; upon the serving of such notice, if such corporation fail to construct said crossings or put up said boards within 60 days from the service of said notice, the parties having control or charge of said roads or streets may proceed to construct said crossings or put up said boards as herein provided, and shall be entitled to recover the amount expended, together with all accruing costs, from such corporation thus refusing or neglecting to construct or put up the same; and such corporation shall be liable for all damages resulting from such neglect to construct such crossings or erect such sign boards as are hereby provided for, said damages to be recovered from any court having jurisdiction thereof, by civil action in the name of the parties injured or having legal control of said roads or streets. But in cities, towns or villages such sign boards shall not be required, unless the corporation shall be required to put up such boards by the officers having charge of such streets.

CANADA.—Railway Act, par. 243.—Sign board at every highway crossed at rail level by any railway, shall be erected and maintained at each crossing, and shall have the words, "RAILWAY CROSSING"

painted on each side thereof in letters at least 6 in. in length. In the Province of Quebec such words shall be in both the English and the French languages. Par. 382.—Every company which fails or neglects to erect and maintain at each crossing where a highway is crossed at rail level by the Railway of the Company, a sign board having the words "RAILWAY CROSSING" painted on each side thereof, in letters at least 6 in. in length and in the Province of Quebec in both the English and the French languages, shall incur a penalty not exceeding forty dollars.

CONNECTICUT.—General Statutes, Revision of 1902, Sec. 3785.—Every company shall keep and maintain at each crossing at grade of any highway at which there is no gate, warning boards of such description as the Commissioners may approve.

DELAWARE.—General Incorporation Law 1899, Sec. 92.—Every railroad corporation formed under this Act shall cause signal boards, well supported by posts, or otherwise, at such heights as to be easily seen by travelers, and not obstructing travel, containing on each side, in capital letters, at least 5 in. high the following inscription, "RAILROAD CROSSING," to be placed and constantly maintained, at such public highway where it is crossed by the railroad at the same level; but such board need not be put up in cities or towns, unless required by the authorities thereof.

FLORIDA.—Acts 1874, Chap. 1987, Sec. 34.—Every railroad company, whenever its track crosses a highway, shall put up large sign boards at or near said crossing with the following inscription in large letters on both sides of the boards: "LOOK OUT FOR THE CARS." In all corporated cities the said company shall cause the bell on the engine to be rung before crossing any of the streets of a city, and their trains shall not go faster through any of the traveled streets of a city than at the rate of four miles per hour.

ILLINOIS.—Hurd's Revised Statutes of Illinois, Sec. 67, Chap. 114.—Every railroad corporation shall cause boards, well supported by posts or otherwise, to be placed and constantly maintained upon each public road or street, where the same is crossed by its railroad on the same level. Said boards shall be elevated so as not to obstruct the travel, and to be easily seen by travelers. On each side of said boards shall be painted in capital letters of at least the size of 9 in. high each, the words "RAILROAD CROSSINGS," or, "LOOK OUT FOR THE CARS." This section shall not apply to streets in cities or incorporated towns or villages, unless such railroad corporation shall be required to put up such boards by the corporate authorities of such cities, towns or villages; provided, that when warning boards have already been erected under existing laws, the maintenance of the same shall be a sufficient compliance with the requirements of this section.

INDIANA.—Chap. 224, Sec. 1.—Be it enacted by the General Assembly of the State of Indiana, that from and after January 1, 1912, it shall be unlawful for any person, firm or corporation, or the lessee or receiver of any person, firm or corporation, who shall own or operate any line of steam or interurban railroad in this State to run trains on the same without installing and maintaining at each grade crossing of its railroad with any public highway, highway crossing signs, to be placed at right angles with the highways where possible, and the construction of same and warning notice to be as follows: A substantial upright post, 13 ft. or more in length, 3½ ft. of which shall be in the ground; a board of wood or metal to be placed not closer to the ground than 7

ft. on this post at right angles with the post, on which shall appear the word "DANGER" in red or black letters; two other boards to be placed diagonally across each other just above the board on which the word "DANGER" is printed, and on one of the two boards the word "RAILROAD" shall appear, and on the other the word "CROSSING." Where two railroads are crossed by the highway, parallel with each other, and not further than 100 ft. distant from each other, a board shall be placed at the top of the diagonal boards on which shall appear the word "TWO"; the boards on which the word "DANGER" is written shall be at least 4 ft. in length; the boards on which the word "RAILROAD CROSSING" is written shall not be less than 5 ft. in length, and where there are two railroads to be crossed the board with the word "TWO" on it shall not be less than 2. ft. in length; the size of all letters on the signs shall not be less than 6. in. high—provided, that the crossing signs of carriers in this state heretofore approved by the Railroad Commission may remain and be taken as a compliance with the terms of this Act; and, provided further, that any other sign than the type described above may be constructed and used with the consent of the Railroad Commission of Indiana. Sec. 2.—Be it further enacted, that any person, firm or corporation, or the lessee or receiver of any person, firm or corporation, violating the provisions of section 1 of this Act are guilty of a misdemeanor and on conviction shall be fined not less than $25 nor more than $200. Sec. 3.—Be it further enacted, that all laws, or parts of laws, that are in conflict with this Act are hereby repealed.

IOWA.—Code of Iowa 1897, Sec. 2054.—Every corporation constructing or operating a railway shall make proper cattle guards where the same enters or leaves any improved or fenced land, and construct at all points where such railway crosses any public road, good, sufficient and safe crossings and cattle guards, and erect at such points, at a sufficient elevation from such a road as to admit of free passage of vehicles of every kind, a sign with large and distinct letters placed thereon, to give notice of the proximity of the railway, and warn persons of the necessity of looking out for trains. Any railway company neglecting or refusing to comply with the provisions of this section shall be liable for all damages sustained by reason of such refusal or neglect, and it shall only be necessary in order to recover for the injured party to prove such neglect or refusal.

KANSAS.—General Statutes 1909, Sec. 1771.—Every railway corporation shall cause boards to be placed, well supported by posts or otherwise, and constantly maintained, across each traveled public road or street, when the same is crossed by the railway on the same level. Said boards shall be elevated so as not to obstruct the travel, and to be easily seen by travelers; and on each side of such boards shall be painted in capital letters, "LOOK OUT FOR THE CARS." But this section shall not apply to streets in cities or towns, unless the corporation shall be required to put up such boards by the city or town authorities, or the officer having charge of such streets.

KENTUCKY.—Kentucky Statutes, Sec. 773.—Every company shall cause signal boards, well supported by posts, or otherwise, at such heights as to be easily seen by travelers, and not obstructing travel, containing on each side, in capital leters at least 5 in. high, the following inscription, "RAILROAD CROSSING," to be placed, and constantly maintained, at every public highway where it is crossed by the railroad at the same level; but such boards need not be put up in cities or towns, unless required by the local authorities thereof.

Sec. 793.—In addition to subjecting itself to any damages that may be caused by such failure or violation be guilty of a misdemeanor, and be fined for such failure or violation not less than $100 nor more than $500, to be recovered by indictment in the Circuit Court of any county through which the company in default operates a line of road, or in the Franklin Circuit Court.

MAINE.—Chapter 51, Sec. 70.—A sign with the words "RAILROAD CROSSING" distinctly painted thereon on each side in letters plainly legible, shall be placed on each side of a way where it is crossed by a railroad, on a post or other structure in such a position as to be easily seen by persons passing upon such way.

MARYLAND.—Code 1912, Art. 23, Sec. 280.—Every railroad company organized under this article shall be required to erect at all points where its road shall cross any public road, at a sufficient elevation from such public road to admit of the free passage of vehicles of every kind, a sign with large and distinct letters placed thereon, to give notice of the proximity of the railroad, and warn persons of the necessity of looking out for the cars; and any company neglecting or refusing to erect such signs shall be liable in damages for all injuries occurring to persons or property from such neglect or refusal.

MASSACHUSETTS.—Acts 1906, Chapter 463, Part II, Sec. 149.—Every railroad corporation shall cause boards, supported by posts, or otherwise, at such heights as to be easily seen by travelers, and not obstructing travel, containing on each side in capital letters at least 9 in. long, the following inscription—"RAILROAD CROSSING," "LOOK OUT FOR THE ENGINE"—to be placed and constantly maintained across each highway or townway where it is crossed by the railroad at the same level; or the corporation may substitute therefor warning boards on each side of the crossing, of such form, size and description as the Board of Railroad Commissioners shall approve.

MICHIGAN.—Sec. 198.—A bell of at least 30 lbs. weight and a steam whistle shall be placed on each locomotive engine, and said whistle shall be twice sharply sounded at least forty rods before the crossing is reached, and after the sounding of the whistle the bell shall be rung continuously until the crossing is passed, under a penalty of $100 for every neglect; provided, that at street crossings within the limits of incorporated cities or villages the sounding of the whistle may be omitted, unless required by the Common Council or Board of Trustees of such city or village; and the company shall also be liable for all damages which shall be sustained by any person by reason of such neglect.

Every railroad corporation shall, and they are hereby required to cause signal boards to be placed, well supported by posts or otherwise, and maintained at each public road or street where the same is crossed by the railroad track at grade. The board shall be so elevated as to not obstruct the travel, and to be seen by people before reaching the crossing, and on each side of such board shall be painted in letters not less than 12 in. in height, the words "RAILROAD CROSSING"; but such boards need not be put up in cities or villages, unless required by the proper officers thereof, or upon the order of the Commissioner of Railroads (railroad commission). This provision shall not apply to signal boards already erected.

MINNESOTA.—Revised laws of Minnesota, 1905, Sec. 1994.—Every such company shall maintain, wherever any of its lines cross a public road, a proper and conspicuous sign indicating such crossing. Any

such company failing to comply with any requirement of this section shall forfeit to the town or municipality having charge of such road $10 for each day that such failure continues.

MISSISSIPPI.—Code of 1906, Sec. 4050.—Every railroad company shall cause a board to be erected and kept up, upon a post or frame sufficiently high, at every place where the railroad may cross a highway, with this inscription, "LOOK OUT FOR THE LOCOMOTIVE," or this, "RAILROAD CROSSING." And on failure to observe this section such company shall be liable to a fine of fifty dollars for each failure, and such offence shall be cognizable before any justice of the peace of the county. A failure to erect the board, as directed, shall be deemed to have occurred once every day the company may continue so to fail or neglect to have the same set up, after two days' notice to an agent or section master; and the company shall be liable to any party injured by such failure or neglect for all damages that he may have sustained thereby.

MISSOURI.—Revised Statutes of Missouri, Sec. 10626.—Every such corporation shall require boards to be placed, well supported by posts or otherwise, and constantly maintained, at all crossings of public roads or streets where gates are not provided, so as to be easily seen by travelers; on each side of such boards shall be painted in capital letters of at least the size of 9 in. each, the words "RAILROAD CROSSING." If such corporation fail to construct or maintain said crossings or to put up such boards as above provided, then the overseers, municipal authorities or other parties having legal control or charge of, or interested in said roads or streets as above stated, shall notify such corporation of the necessity of the construction and erection thereof, which notice or petition shall be in writing and shall be served by delivering a copy of the notice or petition to the agent of the corporation most convenient to the crossing. Upon the service of such notice or petition, if such corporation fail to construct said crossing or to put up said boards within thirty days from the date of said notice or petition, the parties having charge of or interested in said roads or streets may proceed to construct and open said crossings or put up said boards as herein provided, and shall be entitled to recover double the amount expended, together with all cost of the road district, county, municipal, corporation or persons interested living in a town not incorporated at whose expense the said crossing was constructed or said boards erected, in any court of competent jurisdiction, from such corporation refusing to construct or erect the same. And such corporation shall be liable for all damages resulting from such neglect to construct such crossing or erect such boards, said damages to be recovered in the name of the party injured, in any court of competent jurisdiction.

NEW JERSEY.—That every such corporation shall cause boards to be placed well supported by boards or otherwise, and constantly maintained across each traveled public road or street, where the same is crossed by the railroad on the same level; said boards shall be elevated so as not to obstruct the travel and to be easily seen by travelers; and on each side of said boards shall be painted in capital letters of at least the size of nine inches each, the words "LOOK OUT FOR THE LOCOMOTIVE," but this section shall not apply to streets in cities or villages unless the corporation shall be required to put up such boards by the officers having charge of such streets.

NEW YORK—Railroad Law, Sec. 53.—Every railroad corporation shall cause a sign board to be placed well supported and constantly maintained, at every crossing where its road is crossed by a public

highway at grade. Such sign board shall be of a shape and design to be approved by the Public Service Commission and shall have suitable words painted thereon to warn travelers of the existence of such grade crossing. The Commission shall have the power to describe the location and elevation of such sign and the words of warning thereon. The Commission may dispense with the use of such sign boards at such crossings as it may designate in cities and villages.

NORTH DAKOTA.—Revised Code 1905, Sec. 4294.—Every railroad corporation operating a line of road within this state must erect suitable signs of caution at each crossing of its road with a public highway, which sign shall be painted with black Roman or block letters on white background, said letters to be at least 8 in. in length and proportionately broad; said signs shall be placed at the top of posts at least 15 ft. high.

OHIO.—General Code, Sec. 8852.—At all points where its road crosses a public road, at a sufficient elevation from such public road to admit of the free passage of vehicles of every kind, each company shall erect a sign, with large and distinct letters placed thereon, to give notice of the proximity of the railroad, and warn persons to be on the lookout for the locomotive. A company which neglects or refuses to comply with this provision shall be liable in damages for all injuries which occur to persons or property from such neglect or refusal.

OKLAHOMA.—Compiled Laws 1909, Sec. 1385.—Every railroad corporation operating a line of road within this state must erect suitable signs of caution at each crossing of its road with a public highway, which sign shall be painted with black Roman or block letters, on white background, "RAILROAD CROSSING"—"LOOK OUT FOR THE CARS." Said letters to be at least 8 in. in length and proportionately broad; said signs shall be placed at the top of posts at least 15 ft. high.

Sec. 1386.—In case any railroad corporation shall refuse or neglect for a space of thirty days after notice given by the Board of County Commissioners to comply with the provisions of the preceding sections, it shall become the duty of the county commissioners of each county through which any such railroad shall be in operation to erect such signs and the company shall be liable for all expenses so incurred by said commissioners.

PENNSYLVANIA.—In Pennsylvania there is no statutory provision as to crossing signs. The cases as to proper precaution lay down the general rule that due care, according to the circumstances, must be taken to prevent accidents, and the question of whether or not proper precautions (including signs at crossings) have been taken would probably be referred to the jury in case of suit for damages for injuries at a crossing.

RHODE ISLAND.—General Laws, Chapter 215, Sec. 15.—Every railroad corporation shall cause to be erected and to be maintained at every turnpike, highway or public way, where it is crossed by the railroad upon the same level therewith, a suitable sign board upon each side of the crossing; and on each side of said sign board shall be painted in black capital letters of at least the length of 9 in., these words: "RAILROAD CROSSING, STOP, LOOK AND LISTEN." Said sign boards shall be erected and placed under the direction and with the consent of the Railroad Commissioner. Every railroad corporation shall also adopt such other precautionary measures at such grade crossings as shall be deemed proper by the Railroad Commissioner.

SOUTH DAKOTA.—Civil Code, Compiled Laws of South Dakota 1910, Sec. 536.—Every railroad corporation operating a line of road within this state must erect suitable signs of caution at each crossing of its road with a public highway, which sign shall be painted with black Roman or block letters on white background, "RAILROAD CROSSING," "LOOK OUT FOR THE CARS," said letters to be at least 8 in. in length and proportionately broad, said signs to be placed at the top of posts at least 15 ft. high.

TENNESSEE.—Shannon's Code, Sec. 1574.—In order to prevent accidents upon railroads the following precautions shall be observed: The overseers of every public road crossed by a railroad shall place at each crossing a sign marked, "LOOK OUT FOR THE CARS WHEN YOU HEAR THE WHISTLE OR BELL," and the county court shall appropriate money to defray the expenses of said signs; and no engine shall be compelled to blow the whistle or ring the bell at any crossing unless it is so designated.

TEXAS.—Sayle's Civil Statutes, Article 4506.—Such corporations shall erect at all points where its road shall cross any first or second class public road, at a sufficient elevation from such public road to admit of the free passage of vehicles of every kind, a sign with large and distinct letters placed thereon, to give notice of the proximity of the railroad and warn persons of the necessity of looking out for the cars, and any company neglecting or refusing to erect such signs shall be liable in damages for all injuries occurring to persons or property from such neglect or refusal.

VIRGINIA.—Pollard's Code, Sec. 1294-d.—Every railroad company shall cause signal boards, well supported by posts or otherwise, at such heights as to be easily seen by travelers and not obstructing travel, containing on each side in capital letters, at least 5 in. high, the following inscription, "RAILROAD CROSSING," to be placed and constantly maintained, at each public highway where it is crossed by the railroad at the same level, but such board need not be put up in cities or towns, unless required by the local authorities thereof.

WEST VIRGINIA.—Sec. 2359.—Every such corporation shall cause boards to be placed, well supported by posts or otherwise, and constantly maintained across each public road or street, where the same is crossed by the railroad on the same level. Said boards shall be elevated so as not to obstruct the travel, and be easily seen by travelers, and on each side of said boards shall be painted in legible capital letters, "RAILROAD CROSSING, LOOK OUT FOR THE LOCOMOTIVE." Any corporation failing to comply with the provisions of this section within six months after the passage of this chapter as amended, shall, for each crossing at which there is such failure, be fined five dollars for every week the failure may continue.

WASHINGTON.—Laws of Washington 1913, Chapter 128, Sec. 3.—The Public Service Commission of Washington shall require any company operating such a railroad as is described in section 1 of this Act, to erect and maintain, upon such part of its line, at every point where a highway crosses such line, a sign or warning, in form to be prescribed by such commission.

WISCONSIN.—Wisconsin Statutes 1911, par. 5, Sub-Div. A, Sec. 1809.—Every such railroad company or corporation shall erect and maintain at all times at every place where its railroad track crosses a public highway or street, and near such crossings, a large sign board with the following inscription, painted in large letters on each side, "LOOK OUT FOR THE CARS," in such manner as to be visible on the highway track at least 100 ft. distant on each side of such crossing.

RULINGS OF PUBLIC UTILITY COMMISSIONS.

In response to inquiry No. 5, "Rulings of Public Utility Commissions," the following information was received:

CONNECTICUT.—A decree of the Public Utilities Commission, January 24, 1913. On consideration, we do hereby approve of warning boards proposed to be hereafter erected or renewed from time to time, as occasion may require, by the New York, New Haven & Hartford Railroad Company, at crossings of its railroad, by highways at grade, at which there is no gate, said boards to consist of two boards placed crosswise, each 8 ft. in length, one foot in width and 1½ in. in thickness, painted white on both of its sides, each board bearing in black letters on one side the words, "RAILROAD CROSSING," and on the other side the words, "STOP, LOOK AND LISTEN"; and to be used in lieu of those heretofore approved by the Board of Railroad Commissioners and to be of a design shown on blue print plan on file in this office dated December 24, 1912, and entitled "Standard High Way Crossing Sign." Said boards to be securely fastened to a post, consisting of 66-lb. relay rail, or heavier, and when erected, such post to be securely set in the ground, in a concrete bed, to a depth of at least 4 ft. and to be of sufficient height that the lower portion of each of the boards shall be approximately 12 ft. above the surface of the ground.

INDIANA.—Railroad Commission of Indiana, Circular No. 26, August 14, 1908.—One hundred and seventy-three persons were killed while trespassing on the tracks or cars of the railroads in Indiana during the year ending June 30, 1908. While the railroads are not to be held responsible for these deaths, as they are for accidents resulting from negligence, it is an act of humanity and a moral, if not a legal, obligation to prevent this loss of life where it is possible so to do. Accident reports for July and August indicate a large increase in these fatalities, and fatalities at highway grade crossings.

Nine states of the Union make explicit prescriptions with reference to walking on railroad tracks; and three, as all should do, expressly forbid it. The State of Indiana, Burns 1908, Sec. 2280, makes it unlawful only after warning: "The offence defined by the statute consists in entering unlawfully upon the lands of another after having been forbidden to do so by the owner or occupant. The unlawful entry in defiance of the command of the lawful occupant constitutes the offence."

In a recent special case in one of the large cities of the state, where railroad tracks were notoriously and daily used by a large number of citizens as thoroughfares, the Commission called upon the Division Superintendent to take steps under this statute to abate this practice. We are now advised by the railroad company that "warning signs are placed at the principal streets, that the mayor has promised us that he will have policemen placed to notify people that they are trespassing, and that we do not feel it necessary for a member of the Commission to come to this city for the purpose of taking up this question with these people."

Success and progress in the individual case demonstrate that the same work should be undertaken in order that like results may be achieved at many places in this state.

This Commission is of the opinion that a more systematic, general and determined effort should be made by the railroad companies and local authorities to keep trespassers off the tracks. We recommend and direct that you shall place warning signals, indicating "DANGER" in red letters at such places in towns, cities or country, and on such bridges and trestles as are often and repeatedly used by the public for

footways or thoroughfares. We recommend and direct that you shall seek the co-operation of local authorities, using this circular if advisable, after placing the warnings referred to, and that you advise the Commission of the results of your efforts, to the end that we may use our official influence to aid you in any case where local authorities refuse to enforce the law. You will take this most important matter up at once and advise us as indicated herein.

INDIANA.—Railroad Commission of Indiana, Circular No. 77.—For three years this Commission has been urging the installation of highway crossing signs with the word "DANGER" inscribed thereon. Most of the companies have complied. For such that have failed or refused, the General Assembly has prescribed Chapter 224, Acts of 1911, set out hereafter. Notice is hereby given that in all cases where these signs are not installed, and in all cases where the same are not maintained with letters plainly legible, prosecutions will be commenced for the penalties provided by the Act. The Commission has directed its inspectors to report all failures, and this Act will be strictly enforced.

NEW JERSEY.—Board of Public Utility Commissioners.—In the matter of conference with representatives of railroad companies respecting adoption of a standard crossing sign, recommendations: (1) In replacing existing crossing warning signs or erecting new signs, they use a sign conforming substantially to that shown upon the blue print attached hereto, both as to the construction thereof and the notice thereon; (2) that such signs be located at such points as will admit of the best view thereof by persons approaching the railroad crossing; (3) that when such signs are so located that the same cannot be seen by persons upon the highway at a distance of at least 150 ft. from the crossing, an additional sign be erected at a distance of at least 150 ft. from such crossing, which sign shall give notice of the danger and of the distance to the crossing, and (4) that where two independent railroads run in a direction substantially parallel, and within four hundred feet of each other, the lower blade marked, "TWO CROSSINGS," shall be added.

RHODE ISLAND.—Order No. 20 of the Public Utilities Commission of Rhode Island, dated December 20, 1912, on approval of standard highway crossing signs, is as follows: Application of New York, New Haven & Hartford Railroad Company for approval of crossing sign.—Upon consideration, it is ordered, that the approval of the Commission be and the same hereby is given to the Standard Highway Crossing Sign, as shown on plan filed with application.

Appendix B.

ABSTRACTS FROM STATUTES IN REGARD TO TRESPASSING.

CANADA.—Par. 407.—Every person who (a) wilfully leaves open any gate on either side of the railway, provided for the use of any farm crossing, without some person being at or near such gate to prevent animals passing through it on the railway; or (b) not being an officer or employe of the company acting in the discharge of his duty, takes down any part of a railway fence, or (c) turns any horse, cattle or other animal upon or within the inclosure of the railway, except for the purpose of and while crossing the railway in charge of some competent person, using all reasonable care and precaution to avoid accident; or (d) except as authorized by this Act, without the consent of the company, rides, leads or drives any horses or other animals to enter upon the railway, and within the fences and guards thereof, shall, on summary conviction, be liable to a penalty of twenty dollars for such offence.

2. Every such person shall also be liable to the company for any damages to the property of the company, or for which the company may be responsible, by reason of such act or omission.

3. Every person guilty of any offence under this section shall, in addition to the penalty and liability therein provided, be liable to pay to any person injured by reason of the commission of such offence all damages thereby sustained.

Pars. 408 and 409.—Every person not connected with the railway or employed by the company who walks along the tracks thereof except where the same is laid across or along a highway is liable on summary conviction to a penalty not exceeding ten dollars.

Any person who uses any highway at rail level for the purpose of passing on foot along such highway across the railway, except during the time when such highway crossing is used for the passage of carriages, carts, horses or cattle, along the said highway is liable on summary conviction to a penalty not exceeding ten dollars, if (a) the company has erected and completed, pursuant to order of the board, over its railway, at or near in lieu of such highway crossing a foot bridge or foot bridges, for the purpose of enabling persons passing on foot along such highway to cross the railway by means of such bridge or bridges; and (b) such foot bridge is maintained or such foot bridges are maintained by the company in good and efficient repair.

CONNECTICUT.—Public Acts of 1905, Chapter 202.—Every person who shall without right be upon or attach himself to, any engine or car upon the track of a railroad or occupy or be upon any part of the platform or grounds of any station or yard of such railroad, or ride, drive, or lead any beast on said track, shall be fined not more than fifty dollars, or imprisoned not more than thirty days, or both. Every station agent of any such company, who shall know or have immediate information that any person has violated any provision of this section, shall forthwith notify a grand juror or other informing officer of the town in which such offence shall have been committed.

DELAWARE.—Code 1892, Chapter 416, Column 14, Laws of Delaware, Sec. 1.—That if any person shall enter into, or get upon, or upon the platform or steps attached to any railroad car, of whatever kind, for the purpose of riding upon the railroad without the

payment of fare, contrary to the rules of the railroad company, he shall, upon proof thereof, before a justice of the peace, be subject to a penalty of five dollars, which shall be for the use of the school district in which the act shall be committed, and shall be recovered in the name of such district with costs of suit.

Sec. 2.—That it shall be the duty of any constable of this state, or police officer of any city or town, to arrest, without warrant, every such offender and take him before a justice of the peace to be tried for the said offence. Should the penalty and costs not be paid upon judgment rendered, the justice shall commit the offender to some proper place for safe keeping for ten days, and shall not before that time be released therefrom unless the said penalty and costs are paid.

Sec. 3.—That suits for the penalty aforesaid shall be within the jurisdiction of a justice of the peace.

Code of 1892, Sec. 21, Chapter 190, Vol. 19, Laws of Delaware.—If any person shall wilfully enter into, upon, or trespass upon the ways, lands, or premises of another in this state, he shall be guilty of a nuisance. Any constable or other conservator of the peace, the owner or occupier of such ways, lands or premises, his agents, or employes, or any other person or persons whom he, or any of them may call to their or his assistance, shall have authority to arrest such offender, either with or without warrant, either upon the premises, or in immediate flight therefrom, and if with warrant, then at any place, and take him before a justice of the peace, or mayor of a city, in the county where the offence is committed; such justice of the peace or mayor is hereby authorized to hear and determine every such case in a summary manner, and if he shall find such person guilty of the charge, shall for each offence, impose a fine of not more than five dollars and costs. The person so found guilty may also be held in recognizance with good security to keep the peace, and not to trespass for one year, in the penal sum of one hundred dollars. If the fine and costs are not paid, or recognizance not given when recognizance is required, the justice or mayor shall commit such offender to the county prison for a term not exceeding thirty days. All prosecutions, proceedings and costs, where not herein otherwise directed, shall be the same as in other criminal cases before such justices of the peace and mayor. Nothing in this section shall be construed to limit or affect the jurisdiction of justices of the peace under chapter 100 of the Revised Code, or to affect the right of the party injured, to his civil action for damages, as in cases of trespass.

FLORIDA.—That Sec. 3424 of the General Statutes of the State of Florida be, and the same is hereby, amended so as to read as follows: 3424.—Whenever fences or enclosures have been or shall hereafter be dispensed with in any county or part of a county in this state, by reason of any no-fence law, or law making it unlawful for live stock to run at large in such county or part of a county, the laws of this state applicable to offences or trespass against realty or injury thereto, or to property thereon, or connected therewith, and in regard to hunting or fishing, or other kinds of trespass on lands, shall not become inoperative, but shall apply to such unenclosed or unfenced land with the same force and effect as if such enclosures or fences had not been so dispensed with. Notices required to be posted on lands shall be sufficient if the sign board shall have thereon in letters easily seen and read the word "POSTED" in letters not less than two inches long and followed by the owner's name.

IDAHO.—That section 2822 of the Revised Code of the State of Idaho be amended to read as follows: Sec. 2822.—If any passenger on any railroad train refuses to pay his fare, or to exhibit or surrender his ticket, when reasonably requested to do so, or uses abusive, vulgar, obscene or profane language in a car occupied by other passengers, or makes his presence offensive or unsafe to the paid passengers, or if any trespasser be found on any car or train, the conductor and employes of the railway company may put him and his baggage out of the cars or off the train, using no unnecessary force, at any station of the railway company operating such train, which is open at the time of such ejection on stopping the train, but not otherwise. Any conductor or employe of any railway company violating the provisions of this section shall be guilty of a misdemeanor, and the railway company shall be liable for all damages caused thereby.

INDIANA.—Burns' Annotated Indiana Statutes, Revision of 1908, Vol. 1, Sec. 2280.—Whoever, being about to enter unlawfully upon the enclosed or unenclosed land of another, shall be forbidden so to do by the owner, or occupant, or his agent or servant, or who, being unlawfully upon the enclosed or unenclosed land of another, shall be notified to depart therefrom by the owner, or occupant, or his agent or servant, and shall thereafter enter upon such land, or neglect or refuse to depart therefrom shall be guilty of a misdemeanor, and, on conviction, shall be fined not less than five dollars nor more than fifty dollars.

ILLINOIS.—Chapter 114, Sec. 79.—No person or minor shall climb, jump or step, stand upon, cling to, or in any way attach himself to any locomotive engine or car, either stationary or in motion, upon any part of the track of any railroad, unless in so doing he shall be acting in compliance with law, or by permission, under the lawful rules and regulations of the corporation then owning or managing such railroad.

Sec. 80.—Whenever any officer, agent or employe of any railroad corporation shall have any information that any person or minor has violated any of the provisions of the preceding section, and has thereby endangered himself or caused reasonable alarm to others, said officer, agent or employe shall, without unnecessary delay, make complaint of such offence against such person or minor before some justice of the peace.

Sec. 81.—Any person or minor who shall violate any of the provisions of Sec. 79 of this Act shall be punished by a fine not exceeding $25, to be recovered in an action of debt, in the name of the people of the State of Illinois, before a justice of the peace, or, upon conviction, by imprisonment in the county jail, or other place of confinement, for a period not exceeding twelve hours.

Sec. 82.—The several railroad corporations in this state shall without unnecessary delay cause printed copies of the three preceding sections of this Act to be kept posted in conspicuous places at all their stations along their lines of railroad in this state. Every railroad corporation that shall neglect to post, and keep posted, such notices as required by this section, shall, for each offence, forfeit the sum of $25 to be recovered in an action of debt, in the name of the people of the State of Illinois.

IOWA.—Code of Iowa 1897, Sec. 4807.—If any persons maliciously injure, remove or destroy any bridge, rail or plank road, or place or cause to be placed any obstruction on such bridge or road; or wilfully obstruct or injure any public road or highway; or malici-

ously cut, burn or in any way break down, injure or destroy any telephone or telegraph post, or in any way cut, break or injure the wires or any apparatus thereto belonging, he shall be imprisoned in the penitentiary not more than five years, or be fined not exceeding five hundred dollars and imprisoned in the county jail not exceeding one year.

Sec. 4809.—If any person shall wilfully and maliciously place any obstruction on the track of any railroad in the state, or remove any rail therefrom, or in any other way injure such railroad or do any other thing thereto whereby life of any person is or may be endangered, he shall be imprisoned in the penitentiary for life, or for any term not less than two years.

KANSAS.—There are no statutes specifically covering trespassers on right-of-way, but attention is called to the following sections:

Sec. 914, General Statutes, 1909, provides that cities of the first class shall have the power to provide for the punishment of all persons who may in any way wrongfully interfere with or obstruct, injure or destroy any railway track, car, engine, or trucks, or loiter around or about the same, or upon the right-of-way or ground of any railway company.

Sec. 2593.—Any person or persons who shall wilfully remove, break, displace, throw down, destroy or in any manner injure any iron, wooden or other kind of rail or other branches or branch ways, or any part of the tracks, or any bridge, viaduct, culvert, embankment, parapet, switch or other fixtures or any part thereof attached to or connected with the track or tracks of any railroad in the state, in actual operation, or in the course of construction, or which shall hereafter be constructed, or put in operation, or who shall wilfully place any obstruction upon the rails or track of any such railroad, shall on conviction thereof be punished by confinement at hard labor in the penitentiary not less than five nor more than ten years; provided, that if any person or persons, shall by the commission of either or any of the aforesaid offences, occasion the death of any person or persons, the person or persons so offending shall upon conviction be deemed guilty of murder in the first degree, and shall be punished as now provided by law for the punishment of murder in the first degree.

Sec. 2889.—That every person who shall climb upon, hold to or in any manner attach himself to any locomotive engine or freight or passenger car, or train or trains of any character, while the same are in motion or standing still, or who shall ride or attempt to ride upon any locomotive engine, railroad train or trains of any character or in or upon any part thereof, for the purpose or with the intent of stealing a ride thereon, at any place within this state shall be guilty of a misdemeanor; provided, that this section shall not apply to any employe of a railroad company operating such train, locomotive or car, nor to any person having business with or acting under legal authority of such railroad company.

Sec. 9692 is a general statute covering common law trespass and provides for civil damages and criminal liability, but in all probability it has no application to trespass upon railroad property unless the trespasser shall knowingly break a glass or any part of it in a building, or shall voluntarily throw down or open any doors, bars, gates or fences and leave the same open or down.

LOUISIANA.—Acts of State of Louisiana 1908, Act 38, Sec. 1.—Be it enacted by the General Assembly of the State of Louisiana, that any person, other than a railway employe in the discharge of

his duties, who, without authority from the conductor of the train, or permission of the engineer, brakeman or other employes in charge of the train, and without paying the usual fare for such transportation, rides or attempts to ride on the top of any car, coach, engine or tender on any railroad in this state, or on the drawheads between the cars, or under the cars, on truss rods or trucks, or in any freight car, or on the platform of any baggage car, express car or mail car on any train in this state shall be guilty of a misdemeanor.

Sec. 2.—That any person found guilty of violating the first section of this Act shall be guilty of a misdemeanor and shall be punished by a fine of not exceeding fifty dollars, or imprisonment not exceeding six months or work on the street or public roads, at the discretion of the court.

Sec. 3.—That any person charged with violation of the first section of this Act may be tried in any parish of this state through which such trains may pass, in which such violation may have occurred, or may be discovered.

MAINE.—Chapter 52, Sec. 77.—Whoever without right, stands or walks on a railroad track or bridge, or passes over such bridge except by railroad conveyance, forfeits not less than five, nor more than twenty dollars, to be recovered by complaint; and whoever, without right, enters upon any railroad track with any team, or any vehicle however propelled, or drives any team or propels any vehicle upon any railroad track, shall be punished by fine of not less than fifty dollars, or by imprisonment not less than thirty days.

Sec. 78.—A printed copy of the preceding section shall be kept posted in a conspicuous place in every railroad passenger station; for neglect thereof, the corporation forfeits not exceeding one hundred dollars for every offence.

Sec. 79.—No railroad corporation shall be liable for the death of a person walking or being on its ground contrary to law, or to its valid rules and regulations.

MARYLAND.—Code of 1904, Art. 27, Sec. 366.—Any person who shall cling, climb, jump or step or in any other way get upon any part of any locomotive, engine or car, whether the same be freight, passenger, coal, or otherwise, upon any part of the track of any railroad within this state, unless in so doing he acts in compliance with law, or by permission under the rules and regulations of the railroad company or corporation operating and managing such railroad, shall be guilty of a misdemeanor, and upon conviction thereof before any justice of the peace or any court of competent jurisdiction shall be fined not less than one dollar nor more than twenty-five dollars, or be subject to imprisonment in jail or in the house of correction for not more than six months, or to both fine and imprisonment in the discretion of the justice of the peace trying the case, or court before whom the case may be tried; or if any such person be a minor under sixteen years of age, he may in the discretion of the justice of the peace or any court trying the case, be committed to any reformatory institution provided by law, and authorized to receive the same, for such period as the justice of the peace or court may determine, not to exceed two years.

MASSACHUSETTS.—Acts 1906, Chapter 463, part II, Sec. 232.—Whoever without right knowingly stands or walks on a railroad track shall forfeit not less than five nor more than fifty dollars.

MINNESOTA.—Revised laws of Minnesota 1905, Sec. 5124.—Every person who (1) shall displace, remove, injure or destroy a

rail, sleeper, switch, bridge, viaduct, culvert, embankment or structure or any part thereof, attached or appertaining to or connected with a railway, whether operated by steam, electricity or any other motive power; (2) shall place any obstruction upon the track of such a railway, or (3) shall wilfully discharge a loaded firearm, or project or throw a stone or other missile at a railway train, locomotive, car or vehicle standing or moving upon a railway shall be punished as follows:

If thereby the safety of any person is endangered, by imprisonment in the state prison for not more than ten years. In every other case, by imprisonment in the state prison for not more than three years, or by fine of not more than two hundred and fifty dollars or both.

Every person who, without lawful authority, shall break down or carry away any part of any fence, bars or gate at a crossing over any railway track, or plank used for such crossing, or shall destroy or injure any hedge, ditch or other structure used or intended as a fence to inclose any railway tracks, every person using any gate or bars or opening the same for any purpose, at any railway crossing, who shall permit any animal to stray upon a railway track or inclosed right-of-way, or who shall leave such bars down, or gate open, so the animals may stray upon such railway track, and every person who shall lead, drive or turn upon such track any animal for grazing or other purpose, shall be guilty of a misdemeanor, and punished for each such offence by imprisonment in the county jail for not more than thirty days, or by a fine of not less than ten dollars nor more than fifty dollars.

Sec. 5148.—Every person not an employe of a railway company, who, without permission from such company, on foot or with any animal or vehicle, shall enter upon any railway bridge or trestle, or who, without a permit, shall ride, operate or propel a velocipede, track bicycle or tricycle on or along the track of any railway, shall be guilty of a misdemeanor.

MISSOURI.—If any person not connected with, or employed upon the railroad, shall walk upon the track or tracks thereof, except where the same shall be laid across or along a publicly traveled road or street, or at any crossing as hereinbefore provided, and shall receive harm on account thereof, such person shall be deemed to have committed a trespass in so walking upon said track in any action brought by him on account of such harm against the corporation owning such railroad, but not otherwise.

MONTANA.—8316 (404) Use of force not unlawful. To use or attempt to offer to use force or violence upon or towards the person of another is not unlawful in the following cases: (5) When committed by a carrier of passengers or the authorized agent or servants of such carrier, or by any person assisting them at their request in expelling from a carriage, coach, railway car vessel or other vehicle, a passenger who refuses to obey a lawful and reasonable regulation prescribed for the conduct of passengers, if such vehicle has first been stopped at any usual stopping place or near any dwelling house, and the force or violence used is not more than sufficient to expel the offending passenger with a reasonable regard to his personal safety.

4238 (975).—Passengers refusing to pay fare.—If any passenger refuses to pay his fare, or to exhibit or surrender his ticket, when reasonably requested so to do, the conductor and employes of the corporation may put him and his baggage out of the car, using no

unnecessary force, at any usual stopping place, or near any dwelling house, on stopping the train.

NEBRASKA.—Cobby's Ann. Statutes 1911, Sec. 2183.—If any person shall wilfully and maliciously injure or deface any church edifice, school house, dwelling house or other building, its fixtures, books or appurtenances, or shall commit any nuisance therein, or shall purposely and maliciously commit any trespass upon the enclosed grounds attached thereto, or any fixtures placed thereon, or any enclosure or sidewalk about the same, such person shall be fined in any sum not exceeding one hundred dollars.

Sec. 3042.—That any person or persons who shall go upon or pass over any cultivated or enclosed lands of this state, without the consent of the owner or occupant thereof, or who shall do, or whose accompanying dog shall do any damage, to or upon said premises, or to any property thereon shall be deemed guilty of a misdemeanor, and upon conviction thereof shall pay a fine of not less than the amount of damage committed, nor more than double the amount of such damage, and in addition thereto, shall be liable to the person or persons suffering such damages for the amount thereof.

Sec. 3043.—Any person or persons who shall enter or go upon any enclosure or cultivated lands, owned or occupied by another, and shall refuse upon request of the owner, or occupant thereof, to go immediately therefrom, shall for each such refusal be deemed guilty of a misdemeanor, and upon conviction thereof shall pay a fine not less than five dollars, nor more than fifty dollars for each such offence so committed.

NEW YORK.—Sec. 83.—No person other than those connected with or employed upon the railroad shall walk upon or along its track or tracks, except where the same shall be laid across or along streets or highways, in which case he shall not walk upon the track unless necessary to cross the same. Any person riding, leading or driving any horse or other animal upon any railroad, or within the fences and guards thereof, other than at a farm or street or forest crossing, without the consent of the corporation, shall forfeit to the people of the state the sum of ten dollars, and pay all damages sustained thereby to the party aggrieved.

OHIO.—Sec. 12522.—Whoever, being about to enter unlawfully upon the lands or premises of another is forbidden so to do by the owner or occupant, his agent or servant, or being unlawfully upon the lands or premises of another, is notified to depart therefrom, by the owner or occupant, his agent or servant, and thereafter enters upon such lands or premises, or neglects or refuses to depart therefrom, shall be fined not less than one dollar nor more than five dollars.

Sec. 12542.—Whoever draws or drives a two or four wheeled vehicle on or between the rails or tracks or on or along the graded roadway of a steam railroad, unless compelled by necessity so to do, without the knowledge and consent of the owner or controller of such road, shall be fined not less than five dollars nor more than twenty-five dollars.

Sec. 12543.—Whoever climbs, jumps, steps, stands upon, clings or attaches himself to a locomotive, engine or car upon the tracks of a railroad, unless in compliance with law or by permission under the lawful rules and regulations of the corporation managing such railroad, shall be fined not more than twenty-five dollars.

Sec. 12544.—Whoever, at a place other than a private crossing, or for a purpose other than crossing a railroad, rides or drives a

horse or other domestic animal into an enclosure of a railroad or knowingly pemits such animal to go into or to remain in such enclosure, or places within it feed, salt or other things to induce such animal to enter into such enclosure or upon the tracks of such railroad, or, while constructing a private crossing, permits a fence to remain down or open for a longer time than is necessary to construct or use such crossing, shall be fined not more than ten dollars or imprisoned not less than ten days nor more than thirty days.

Sec. 12545.—Each ten hours an animal named in the next preceding section is knowingly permitted to remain in an enclosure or upon a track described therein, shall be an additional offence, and such animal shall not be exempt from execution for a fine or costs imposed under such section.

OKLAHOMA.—Sec. 1444.—Railway companies organized under the laws of this state, or doing business within the state, are hereby authorized and empowered at their own expense to appoint and employ policemen at such stations or other places on the line of their railroads within this state, as said companies may deem necessary for the protection of their property, and the preservation of order on their premises, and in and about their cars, depots, depot grounds, yards, buildings or other structures; and said policemen shall have power and authority to arrest with or without warrant, any person or persons who shall commit any offences against the laws of this state, or the ordinances of any town, city or other municipality, when such offence shall have been committed upon the premises of said companies, or in and about their cars, depots, depot grounds, yards, buildings or other structures; and shall also have the authority of sheriffs, constables and peace officers in regard to the arrest and apprehension of any such offenders, in or about the premises or appurtenances aforesaid; but in case of the arrest by said policemen of any person without warrant, they shall forthwith take such offender before some justice of the peace or other magistrate having jurisdiction, and make complaint against such offender, according to law. Nothing herein contained shall be construed as restricting the lawful rights, powers or privileges of any sheriff, constable, policeman or peace officer within their respective jurisdiction, and for the official acts of such policeman or policemen the railroad company making such appointments shall be held responsible to the same extent as for the acts of any of its general agents or employes.

OREGON.—Sec. 1977.—If any person shall wilfully break down, injure, remove or destroy any free or toll bridge, railway, plank road, macadamized road, telegraph or telephone posts, or wires, or any gate upon any such road, or any lock or embankment of any canal, such person, upon conviction thereof, shall be punished by imprisonment in the penitentiary for not less than six months nor more than two years, or by fine not less than $50 nor more than $1,000.

Sec. 2254.—Every person who shall, at any place within this state, ride or attempt to ride upon any locomotive, engine, railroad car, railroad train, or trains of any character, or in or upon any part thereof for the purpose or with the intent of stealing a ride thereon; or who shall for a like purpose, or with like intent, at any place within this state, climb upon, hold to, or in any manner attach himself to any locomotive engine or railroad car or railroad trains of any character, while the same are in motion or standing still, shall be guilty of a misdemeanor; provided, however, that this section shall not apply to any employe of a railroad company operating such train, locomotive or car, nor to any person having business with or acting under legal authority of such rail-

road company, nor to any passenger for hire lawfully entitled to ride upon or in any passenger train.

Sec. 2255.—Authority is hereby given to and conferred upon railroad conductors, brakemen, firemen and engineers of railroad trains to immediately arrest any person or persons violating section 2254 without warrant or other process, and to call upon any bystanders or other persons for assistance whenever the same may be necessary to enable them to make such arrest. Any person authorized under this act to make arrests may cause the person or persons so arrested to be delivered to any sheriff, or other peace officer, to be prosecuted for such offence; provided, however, nothing in this Act shall be construed to restrict the authority or duty of any regular peace officer within the state to make arrests for said offences.

Lord's Oregon Laws, Sec. 2255.—It shall be unlawful for any person to run or operate any push car, velocipede, hand car or any other wheeled contrivance upon any railroad track in the state. Nothing in this Act shall be construed to apply to any of the employes operating such railroad whose duty it is to keep such railroad track in condition as a common carrier.

Section 2253 provides for punishment by a fine of not less than $20 or more than $100, or by imprisonment in jail not less than ten nor more than fifty days, or both fine and imprisonment.

PENNSYLVANIA.—Purdon's Digest, 13th edition, Vol. 4, Sec. 227.—Any person found entering or being in or upon any railroad engine or car, whether the same be passenger, freight, coal or other car, on any railroad in any city or county in this commonwealth, contrary to the rules of the person or persons, or corporation, owning or operating the same, and with the intention of being in or upon, riding or traveling upon such engine or car without paying fare, or committing larceny, violence or destruction thereon, or of threatening, intimidating or assaulting travelers or other persons upon such engine or cars, shall, upon conviction, forfeit and pay a penalty of not less than $5 nor more than $15, which penalty shall be paid to the treasurer of the school district in which said offence was committed, for the use of said district or be committed to the county jail of said county for a period not exceeding ten days, either or both, at the discretion of the magistrate, and in default of payment of fine as aforesaid and costs, then the said alderman, magistrate or justice of the peace shall commit the person so convicted to the jail of the county wherein the offence was committed for a further period not exceeding ten days.

RHODE ISLAND.—Public laws of Rhode Island, Chapter 953, Sec. 35.—Every person who, without right knowingly, stands, or walks, or rides a bicycle on the private right of way of any railroad or railway operated by steam or other power, except for the purpose of crossing it at a highway or other authorized crossing, shall be fined not less than $5 nor more than $20. Any person violating this section may be arrested without a warrant by any police officer or any special railroad police officer and proceeded against according to law.

Sec. 36.—A printed copy of the preceding section shall be conspicuously posted in a public place in or upon each passenger station of every railroad and railway, operated by steam or other power, in this state.

SOUTH DAKOTA.—Code of South Dakota, Sec. 702.—(1) Every person who maliciously either removes, displaces, injures or destroys any part of any railroad, whether for steam, electricity or horse cars, or any track of any railroad, or any branch or branchway, switch, turnout, bridge, viaduct, culvert, embankment, station, station house or other

structure or fixture, or any part thereof, attached to or connected with any railroad; or (2) places any obstruction upon the rails or track of any railroad or any branch, branchway, or turnout, connected with any railroad, is punishable by imprisonment in the state prison not exceeding four years, or in a county jail not less than six months.

TENNESSEE.—Shannon's Code, Sec. 1574, par. 4.—Every railroad company shall keep the engineer, fireman, or some other person upon the locomotive, always on the lookout ahead; and when any person, animal or other obstruction appears upon the road, the alarm whistle shall be sounded, the brakes put down, and every possible means employed to stop the train and prevent an accident.

UTAH.—Chapter 41, Sec. 4341.—Every person who clandestinely enters into or upon any railroad car for the purpose and with the intention of riding or being transported thereon, or who having entered into or upon any railroad car, rides over any railroad line or portion thereof in this state without the knowledge and consent of the company or person, owning or operating such car or railroad, and with the intention to defraud such company or person of the fare or compensation for such transportation, shall be guilty of a misdeameanor, and, upon conviction thereof, shall be punished by imprisonment in the county jail not exceeding fifty days, or by a fine in any sum less than $50, or by both.

Sec. 4342.—Every person, being at the time a servant or employe of any railroad company, who aids, abets, assists, counsels, advises, or encourages another person to enter into or ride upon any railroad car for the purpose, with the intention, and, in a manner specified in the section, shall be guilty of a misdemeanor.

VIRGINIA.—Sec. 3725.—If any person maliciously obstructs, remove, or injure any part of a canal, railroad, or urban, suburban or interurban electric railway, or any lines of any electric power company, or any bridges or fixtures thereof, or maliciously obstruct, tamper with, injure, or remove any machinery, engine, car, trolley, supply or return wires, or any other work thereof, or maliciously open, close, displace, tamper with, or injure any switch, switch point, or switch lever, or signal of any such company, whereby the life of any passenger or other person on such canal, railroad, urban, suburban or interurban electric railway, is put in peril, he shall be confined in the penitentiary not less than two years nor more than ten years; and, in the event of the death of any passenger or other person resulting from such malicious act, the person so offending shall be deemed guilty of murder, the degree to be determined by the jury. If any act be committed unlawfully, but not maliciously, the person so offending shall upon conviction thereof, be punished by confinement in the penitentiary not less than one nor more than three years, or, at the discretion of the jury, be confined in jail not to exceed twelve months and fined not less than $100 nor more than $500.

Sec. 3726.—If any person be on the track of a railroad within one hundred yards of an approaching train otherwise than in passing over such road at a public or private crossing, or wilfully ride, drive or lead any animals, or contrive for any animal to go on such track, except in crossing, as aforesaid, without the consent of the railroad company or person operating such road, he shall be fined not less than $10 nor more than $100.

Sec. 3726a.—If any person, not being a passenger or employe, but a trespasser, shall be found upon any railroad car or train of any railroad in this state, or shall jump on or off any car or train on its

arrival, stay or departure at or from any station or depot of such railroad, or on the passage of any such car or train over any part of any such railroad, such person so offending shall be deemed guilty of a misdemeanor and, on conviction, shall be punished by a fine of not less than $2.50, nor more than $10, or by imprisonment in jail not exceeding thirty days, or both.

Sec. 3726b.—If any person, not being a passenger or employe, shall be found trespassing upon and railroad car or train of any railroad in this state, by riding on any car or any part thereof, on its arrival, stay or departure at or from any station or depot of such railroad, or on the passage of any such car or train over any part of any such railroad, such person so offending shall be deemed a disorderly person and, on conviction as such, shall be punished by a fine of not less than two dollars and fifty cents nor exceeding twenty-five dollars, or by imprisonment in jail not exceeding thirty days, or both.

Sec. 3726c.—If any person shall wilfully and maliciously take or remove the waste or packing from out any journal box, or boxes. of any locomotive, engine, tender, carriage, coach, car, caboose, or truck, used or operated upon any railroad, whether the same be operated by steam or electricity, he shall, upon conviction thereof, be confined in the penitentiary not less than one nor more than three years, or in the county or city jail not less than one nor more than twelve months, or fined not exceeding $500.

Sec. 3726d.—If any person maliciously shoot at, or maliciously throw any stones, or other missile at or against any train, or cars on any railroad or other transportation company, or at, or against, any vessel or other water craft, whereby the life of any passenger or other person on such train or car, or on such vessel, or other water craft, may be put in peril, the person or persons so offending shall, upon conviction thereof, be punished by confinement in the penitentiary not less than five nor more than ten years; and in the event of the death of any passenger or other person resulting from such malicious shooting or throwing, the person so offending shall be deemed guilty of murder, the degree to be determined by the jury.

If any such act be committed unlawfully, but not maliciously, the person so offending shall, upon conviction thereof, be punished by confinement in the penitentiary not less than one, nor more than three years, or, at the discretion of the jury be confined in jail not to exceed twelve months, and fined not less than $100 nor more than $500.

Sec. 3726e.—If any person maliciously injure, destroy or remove any switch lamp, flag, or other signal used by any railroad company, whereby the life of any traveler, employes, or other persons is or may be put in peril, he shall be punished by confinement in the penitentiary not less than two nor more than ten years; and in the event of the death of any traveler, employe, or other person resulting from such malicious injuring, destroying, or removing, the person so offending shall be deemed guilty of murder, the degree to be determined by the jury. If such act be done unlawfully, but not maliciously, the offender shall, in the discretion of the jury, be confined in the penitentiary not less than one nor more than five years, or be confined in jail not exceeding twelve months, and fined not exceeding $500. And in the event of the death of any traveler, employe, or other person, resulting from such unlawful injuring, destroying or removing, the person so offending shall be deemed guilty of murder or manslaughter, as the jury may determine.

Sec. 3727.—If any person, with a view to the recovery of damages against a railroad company, wilfully ride, drive, or lead any animal or otherwise contrive for any animal to go on the railroad

track of such company, and such animal is by reason thereof killed or injured, he shall be confined in the penitentiary not less than one nor more than ten years, or, in the discretion of the jury, confined in jail not exceeding one year and fined not exceeding five thousand dollars.

Sec. 3728.—If any person wilfully break, injure or destroy any fence of a railroad company, he shall be fined not less than ten nor more than one hundred dollars, and be confined in jail not exceeding six months.

Sec. 3728a.—Any person who shall maliciously cut or break down, injure, or destroy any fence erected along the line of any railroad, for the purpose of fencing the track or depot or depot grounds of such road, or shall break down, injure or destroy any cattle stop along the line of any railroad, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall be punished by confinement in jail not less than fifteen days or fined not less than ten dollars or both.

Sec. 3779a.—If any person, whether a passenger or not, shall, while in any car or caboose, or on any part of a train carrying passengers or employes of any railroad or street passenger railway behaves in a riotous or disorderly manner, he shall be guilty of a misdemeanor, and, on conviction thereof, shall be fined not less than five nor more than fifty dollars, or be committed to jail not less than one month nor more than six months, or both, in the discretion of the court. The agent or employes in charge of the train, car, or caboose, may require such person to discontinue his riotous or disorderly conduct, and if he refuses to do so, may eject him with the aid, if necessary, of any other persons who may be called upon for the purpose.

WASHINGTON.—Chapter 128, Sec. 1.—It shall be unlawful for any person to go upon or to be upon that portion of any railroad right-of-way upon which is constructed and operated more than one main line track or upon which is constructed and operated any electric interurban line of one or more tracks where the electricity is transmitted by a third rail.

Sec. 8.—The foregoing section shall not be construed to include that part of any right-of-way embraced in any highway crossing or any lawful private crossing, and shall not be construed to prohibit officers or employes of any such railroad or public officers from going or being upon any portion of the right of way in the performance of their duties.

Sec. 4.—Any person violating the provisions of section one of this Act shall be guilty of a misdemeanor.

Remington & Bollinger's Annotated Code and Statutes of Washington, Sec. 2650.—Every person who, in such manner as might, if not discovered, endanger the safety of any engine, motor car or train, or any person thereon, shall in any manner interfere or tamper with or obstruct any switch, block, rail, roadbed, sleeper, viaduct, bridge, trestle culvert embankment structure or appliance pertaining to or connected with any railroad; or any train, engine, motor or car on such railway; and every person who shall discharge any firearm or throw any dangerous missile at any train, motor or car on any railway shall be punished by imprisonment in the state penitentiary for not more than twenty-five years.

Sec. 2664.—Every person who, without permission from the person or corporation owning or operating the same, shall enter or take any animal or vehicle upon any railway, bridge or trestle, or

ride, operate or propel, a hand car, velocipede, track bicycle or tricycle on or along the track of any railway shall be guilty of a misdemeanor.

WEST VIRGINIA.—Code of 1906, Sec. 4282.—If any person, not being a passenger or employe, shall be found trespassing upon any railroad car or train of any railroad in this state, by jumping on or off any car or train on its arrival, stay or departure at or from any such car, station or depot of such railroad, or on the passage of any such car or train over any part of any such railroad, such person so offending shall be deemed a disorderly person, and on conviction as such, shall be punished by a fine not exceeding twenty-five dollars, or by an imprisonment in the county jail not exceeding thirty days, or both.

REPORT OF COMMITTEE XIX—ON CONSERVATION OF NATURAL RESOURCES.

WILLIAM MCNAB, *Chairman;*
C. H. FISK, *Vice-Chairman;*
R. H. AISHTON,
G. A. MOUNTAIN,
MOSES BURPEE,
W. L. PARK,
F. F. BUSTEED,
G. H. WEBB,
A. W. CARPENTER,
R. C. YOUNG,

Committee.

To the Members of the American Railway Engineering Association:

The Committee on Conservation of Natural Resources was formed in 1908, its object being to keep in touch with the general work of Federal, State and Provincial Conservation organizations, and more particularly with the features of such work of specific and general interest to railways, in order to report on such proceedings to this Association. It is noted with satisfaction that the influence of the spirit of conservation, in a broad and complete sense, is rapidly enlarging, and the various sections of the Continent, acting through the regular organizations, are becoming more impressed with a desire that the great principles embraced therein should receive prompt and more general attention.

At the outset of the national general movement for Conservation of Natural Resources, and more particularly at the time this Committee was formed, there is no doubt that the term "Conservation" had created a somewhat hazy impression in the minds of a large proportion of our population, and in some instances its meaning seemed synonymous with the preservation of forest wealth, by reason simply of a desire to restrain or restrict wanton methods of the timber exploiter. The movement however, has gone steadily through an evolutionary educational process in physical science, commercial possibilities and social and domestic economics, by which its general scope has been enlarged. It now embraces principles of preservation, prevention of waste, the efficient development of every variety of our natural resources, and the study of how to make the wealth-producing power, as represented by such features, perpetual by judicious conservation.

Much time and thought have been spent in the past in devising ways and means for benefiting posterity and preventing the deprivation to them of what may be termed part of their birthright. These means have, however, been more or less associated simply with restricting the use of natural resources by an existing generation, lest otherwise posterity should suffer thereby, instead of applying certain principles of conservation that will permit each succeeding generation to concurrently make use of these resources in such a way as to be stimulants to every department of industrial activity and national life and expansion.

The Committee has kept in touch with the work of two great organizations, viz., the National Conservation Congress and the Commission of

Conservation for the Dominion of Canada, and it has been able to secure a mass of valuable data touching forests, timber preservation, water powers, fuels (including oil), etc. They were unable, however, as yet, to obtain certain details in order to make the statement sufficiently comprehensive, and as this report is merely one noting progress, it has been deemed advisable to defer publishing such data until it can be correlated in order to represent the whole continent.

The Fifth National Conservation Congress was held in Washington, D. C., November 17, 18, 19 and 20, 1913. The Congress was made up of delegates from all States of the Union and from Canada. They were representatives of States, cities, counties, universities and colleges, public and commercial organizations, conservation associations, technical societies and other National and State organizations interested in the work of Conservation. For the first time in the history of the National Conservation Congress, its meeting had the advantage of the presence among its members of a number of distinguished engineers representing more than twenty thousand engineers of the country who are enrolled in the ranks of the American Society of Civil Engineers, the American Institute of Electrical Engineers, the American Society of Mechanical Engineers and the American Institute of Mining Engineers. The Water Power Committee of the Conservation Congress had no less than six able engineers in its membership. There were standing committees on the following subjects: Forestry, Water Power, Minerals, Land and Agriculture, Education, Vital Resources, Food, Civics, Wild Life Protection, National Parks and Mammoth Cave.

The American Railway Engineering Association had three delegates at the Congress, viz., Mr. C. H. Fisk, Vice-Chairman of this Committee, together with Messrs. R. C. Young and A. W. Carpenter, members of the Committee.

The topics announced for the principal consideration of the Congress were "Water Power" and "Forestry." Preceding these, a number of addresses were made on other subjects, including conservation of the soil for agricultural purposes, improvements, for the benefit of farmer and consumer, in conditions for marketing farm products, the bettering of farm-life conditions, and the prevention of food adulteration. It was stated that less than 40 per cent. of the arable land in the Union is reasonably well cultivated, and less than 12 per cent. is yielding full returns. Very striking examples of increased productivity of soil, due to intelligent and scientific use of fertilizers, were cited. It was announced that the Federal Government, through the Department of Agriculture, is to offer to co-operate with the States in the inauguration of a new system of instruction to farmers in proper land cultivation; the work to be done through the agency of demonstrators who will undertake the management of a piece of any farmer's land, at his request, and thus bring the education directly to the farmer. The Department of Agriculture also proposes a study for the improvement of farm marketing, transportation

and temporary storage of farm supplies and other general assistance to farmer and consumer in the matter of prices received and paid for farm products. It is needless to point out the benefit to our railways in any increase in the output of the farms along their lines and in the increased prosperity of the farmers. Any movement of this kind should receive the hearty approval and co-operation of the members of this Association.

The greater portion of the time of the Congress was taken up with the subject of "Water Power." The Committee of the Congress on Water Power presented three reports, a majority report, a minority report and a report containing unanimous recommendations of the Committee. The unanimous report recommended that the development of water power, under proper safeguards of the public interest, should be encouraged and hastened, and set forth principles recommended to govern the granting of a privilege to use a water power. These principles, briefly stated, were that the grant should be for a definite period, sufficient to be financially attractive to investors, irrevocable except for cause, reviewable by the courts; thereafter should continue subject to revocation by the proper governmental authority upon payment of the value of the physical property and improvements of the grantee; the privilege to be unassignable except with the approval of the Government and to be granted only on condition of development of the whole capacity of the power-site as rapidly as use demands; the right to receive compensation for the privilege to be reserved to the Government, State or Federal, which grants the privilege—in normal cases the Government to share increasingly in profits above a certain reasonable limit; and other details in connection with these fundamentals. Both the majority and the minority reports urged the prompt development of water power both for the benefits to be derived directly therefrom and in the saving in coal, oil and gas—the non-replaceable power-producing resources which would otherwise be employed. Both reports pointed out that the Federal laws are at present discouraging to the development of water power and urged the enactment of laws more favorable to investors. The principal differences between the majority and minority reports were in the matters of regulation of rates and control, the majority being more liberal in these matters and expressing confidence in the ability of State public service commissions to regulate public service corporations in intrastate business, while the minority report expressed fear of centralization of monopolistic control and urged Federal Government control. The majority report considered very fully the development of water power in navigable streams and suggested the possibility of combining with the development of navigation. The recent Supreme Court decision in the Chandler-Dunbar case seems to provide that any streams not now navigable will come under the Federal Government jurisdiction if rendered navigable in any way. In case of a general development of water power it would appear that many streams now not navigable nor under Federal jurisdiction would be ren-

dered so, with all the attendant requirements for railroad crossings. This is mentioned merely for information and not to suggest opposition to the development of water power. The Congress first adopted the unanimous recommendations and later adopted a declaration of principles recognizing present concentrations of water-power control, accentuating the need for "firm and effective control" on the part of the public and resolving that "no water power now owned or controlled by the public" should be disposed of in perpetuity or removed from public ownership.

There was practically no discussion of the merits of the Water Power reports, most of the time given to the subject being taken up by speeches on State vs. Federal Government control, several Western and Southern States delegations being strongly in favor of State control. The voting was, however, nearly three to one in favor of Federal Government control.

In the consideration of Forestry, there was a marked trend from the theoretical to the practical, it being pointed out that forestry would not be practiced as a science by individual owners and lumbermen until it can be made clear that it will be profitable. One detriment to the growing of trees for lumber is the present general method of taxing timber lands. One phase of forestry is being practiced by the lumbermen, namely, the adoption of improved methods for protection against fire, and that with great success. It was stated that the Federal Government is making great progress in the purchase of cut-over timber lands to form the Appalachian Reserve and in the replanting of these lands.

The questions discussed, such as the proper control of irrigated lands, the robbing of the soil and preserving the soil fertility, conservation of human life, and the control of our water power, all interest railways more or less directly, but do not interest us as railway engineers until they begin to affect the revenue and the prosperity of the railway. The question of control of water power might be interesting to the railway engineer under two aspects:

(1) In case railways contemplate electrifying their system and handling their traffic by electric power.

(2) When the use of electric power decreases the consumption of coal to the extent of its interfering with the revenue of the railway and the prosperity of the coal-mining communities.

The large number and wide representation of the delegates attending the Congress and the close interest manifested in all the proceedings was very impressive and indicative of the intense interest of the Nation in the work of taking care of its natural resources and of developing them for the good of the people as a whole, as opposed to development for the benefit and enrichment of a few, and an illuminating statement on the general object of Conservation was made in the President's address, in which he stated that "Conservation does not mean reservation," but it means "wise use."

CANADA.

The Committee announces with satisfaction that it is also in close personal touch with the Conservation Commission of the Dominion of Canada, and has pleasure in stating that that body is doing excellent work along its particular lines of usefulness. Some general but useful statistics which the Committee has for compilation will, when published, be authoritative, as they have been received from the highest official sources. A question which has been asked in a letter from one of our members engaged in railway work in northern Canada concerning oil for fuel may be interesting. The nature of the inquiry is as follows: "I take the liberty of suggesting that the question of oil fuel is one which our Association, through its Committee on Conservation of Natural Resources, should consider fully and in great detail. We engineers who are working in the far North are, in a few years, going to be confronted with the question of fuel costs * * * ." The Committee would state that in many lines of industry, oil fuel is rapidly displacing coal. The great increase in oil-burning mileage of railways is due to the fact of the saving in operating expenses. In Canada the Great Northern Railway uses oil exclusively on 115 miles of the Cascade Division. The Canadian Pacific Railway has installed oil burners on its main line between Kamloops, B. C., and Field, B. C., a distance of 260 miles; also on the Arrow and Okanagan branches, an aggregate length of 79 miles; and on the Esquimalt & Nanaimo Railway, between Victoria and Alberni on Vancouver Island, a distance of 134 miles. Fifty per cent. of the locomotives on the division between North Bend and Vancouver have been converted to oil burners, and the remainder are now in course of alteration. The Grand Trunk Pacific contemplates the installation of oil-burning engines on the Mountain Division as soon as its line is completed. The steamships of the Grand Trunk Pacific, as well as those of the Canadian Pacific, operating on the Pacific Coast, burn oil, and other Pacific Coast vessels have been changed from coal burners to oil burners. The oil is obtained from the California fields. No fuel oil is as yet produced in Canada, but if the Athabaska fields are successfully developed, as seems probable, the supply will be practically unlimited.

As a mark of the importance that the subject of Conservation is held in Canada and of the interest the railways have in the proper care and exploitation of natural resources, it may be stated that some of the railway systems are entering into the spirit of it in a keen and business-like manner. One of the great transcontinental roads—the Canadian Pacific—has created a Department of Natural Resources under the immediate direction of a competent engineer and administrator. This department controls all the natural resources of the company, such as lands, mines and industrial and forestry branches, and it is particularly interested in seeing that every acre tributary to its lines produces what the soil is specially adapted for, and that it will furnish a full complement of such products, whether they be agricultural or forest.

One of the important features of practical forest conservation is the development of methods whereby the so-called inferior species of timber may be used in the place of more valuable species, the supplies of which are becoming rapidly reduced, or the prices of which have become so high as to render impracticable their use for many purposes. This feature is the lengthening of the life of timbers by preservative treatment, thereby decreasing the drain upon the forests.

The practice of using preservative treatment for ties in Canada is of quite recent origin.

The first plant of any size to be erected was built at North Transcona, about five miles from Winnipeg, Manitoba. It is operating under a contract with the Canadian Pacific Railway Company. The industry of wood preserving is certain to expand as soon as the more or less experimental period is passed. In using the word "experimental," it is not meant that there is any doubt as to financial results, but there is doubt as to what woods ought to be treated; as to what preservative treatment should be given, the effect of climatic and other conditions, cost of different preservatives laid down at the plant, differences in wood of the same species, supply and prices of timber, amount and weight of traffic over a given line, the use or non-use of tie-plates, weight of rail, etc. These are all very important factors in determining the advisability of a preservative treatment.

Your Committee therefore earnestly recommends to the members of this Association the study and practice of timber preservation, both as an economic proposition and as a check on the rapid depletion of our forests.

"CONSERVATION" DEFINED.

As a matter of interest and information to our members, the following extract from Gifford Pinchot's work, entitled, "The Fight for Conservation," is submitted, in the hope that it will show the true spirit in which the great question of Conservation of Natural Resources should be considered and dealt with:

"The principles which govern the Conservation movement, like all great and effective things, are simple and easily understood. Yet it is often hard to make the simple, easy and direct facts about a movement of this kind known to the people generally.

"The first great fact about Conservation is that it stands for development. There has been a fundamental misconception that Conservation means nothing but the husbanding of resources for future generations. There could be no more serious mistake. Conservation does mean provision for the future, but it means also and first of all the recognition of the right of the present generation to the fullest necessary use of all the resources with which this country is so abundantly blessed. Conservation demands the welfare of this generation first, and afterward the welfare of the generations to follow.

"The first principle of Conservation is development, the use of the natural resources now existing on this Continent for the benefit of the people who live here now. There may be just as much waste in neglecting the development and use of certain natural resources as there is in their

destruction. We have a limited supply of coal, and only a limited supply. Whether it is to last for a hundred or a hundred and fifty or a thousand years, the coal is limited in amount, unless through geological changes which we shall not live to see, there will never be any more of it than there is now. But coal is in a sense the vital essence of our civilization. If it can be preserved, if the life of the mines can be extended, if by preventing waste there can be more coal left in this country after we of this generation have made every needed use of this source of power, then we shall have deserved well of our descendants.

"Conservation stands emphatically for the development and use of water power now, without delay. It stands for the immediate construction of navigable waterways under a broad and comprehensive plan as assistants to the railways. More coal and more iron are required to move a ton of freight by rail than by water, three to one. In every case and in every direction the Conservation movement has development for its first principle, and at the very beginning of its work. The development of our natural resources and the fullest use of them for the present generation is the first duty of this generation. So much for development.

"In the second place, Conservation stands for the prevention of waste. There has come gradually in this country an understanding that waste is not a good thing and that the attack on waste is an industrial necessity. I recall very well indeed how, in the early days of forest fires, they were considered simply and solely as acts of God, against which any opposition was hopeless and any attempt to control them not merely hopeless but childish. It was assumed that they came in the natural order of things, as inevitably as the seasons or the rising and setting of the sun. To-day we understand that forest fires are wholly within the control of man. So we are coming in like manner to understand that the prevention of waste in all other directions is a simple matter of good business. The first duty of the human race is to control the earth it lives upon.

"We are in a position more and more completely to say how far the waste and destruction of natural resources are to be allowed to go on and where they are to stop. It is curious that the effort to stop waste, like the effort to stop forest fires, has often been considered as a matter controlled wholly by economic law. I think there could be no greater mistake. Forest fires were allowed to burn long after the people had means to stop them. The idea that men were helpless in the face of them held long after the time had passed when the means of control were fully within our reach. It was the old story that 'as a man thinketh, so is he'; we came to see that we could stop forest fires, and we found that the means had been at hand. When at length we came to see that the control of logging in certain directions was profitable, we found it had long been possible. In all these matters of waste of natural resources, the education of the people to understand that they can stop the leakage comes before the actual stopping and after the means of stopping it have long been ready at our hands.

"In addition to the principles of development and preservation of our resources there is a third principle. It is this: The natural resources must be developed and preserved for the benefit of the many, and not merely for the profit of a few. We are coming to understand in this country that public action for public benefit has a very much wider field to cover and a much larger part to play than was the case when there were resources enough for everyone, and before certain constitutional provisions had given so tremendously strong a position to vested rights and property in general.

"The Conservation idea covers a wider range than the field of natural resources alone. Conservation means the greatest good to the greatest number for the longest time. One of its great contributions is just this,

that it has added to the worn and well-known phrase, 'the greatest good to the greatest number,' the additional words, 'for the longest time,' thus recognizing that this Nation of ours must be made to endure as the best possible home for all its people.

"Conservation advocates the use of foresight, prudence, thrift, and intelligence in dealing with public matters, for the same reasons and in the same way that we each use foresight, prudence, thrift and intelligence in dealing with our own private affairs. It proclaims the right and duty of the people to act for the benefit of the people. Conservation demands the application of common sense to the common problems for the common good.

"The principles of Conservation thus described—development, preservation, the common good—have a general application which is growing rapidly wider. The development of resources and the prevention of waste and loss, the protection of the public interests, by foresight, prudence, and the ordinary business and homemaking virtues, all these apply to other things as well as to the natural resources. There is, in fact, no interest of the people to which the principles of Conservation do not apply.

"The Conservation point of view is valuable in the education of our people as well as in forestry; it applies to the body politic as well as to the earth and its minerals. A municipal franchise is as properly within its sphere as a franchise for water power. The same point of view governs in both. It applies as much to the subject of good roads as to waterways, and the training of our people in citizenship is as germane to it as the productiveness of the earth. The application of common sense to any problem for the Nation's good will lead directly to national efficiency wherever applied. In other words, and that is the burden of the message, we are coming to see the logical and inevitable outcome that these principles, which arose in forestry and have their bloom in the conservation of natural resources, will have their fruit in the increase and promotion of national efficiency along other lines of national life.

"The outgrowth of Conservation, the inevitable result, is national efficiency. In the great commercial struggle between nations which is eventually to determine the welfare of all, national efficiency will be the deciding factor. So from every point of view conservation is a good thing for the American people."

Respectfully submitted,

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

R. N. BEGIEN, *Chairman;*
C. P. HOWARD, *Vice-Chairman;*
F. H. ALFRED,
A. C. DENNIS,
F. W. GREEN,
L. C. HARTLEY,
P. M. LABACH,
J. DEN. MACOMB,
C. W. P. RAMSEY,
A. K. SHURTLEFF,
F. W. SMITH,
H. J. SIMMONS,
E. C. SCHMIDT,
JOHN G. SULLIVAN,
WALTER LORING WEBB,
M. A. ZOOK,

Committee.

To the Members of the American Railway Engineering Association:

The Committee on Economics of Railway Location has not held any meetings during the year. The conditions affecting railway operation brought about by the great flood of March and April, 1913, were such that the energies of a great many members of the Committee were taken up in overcoming the results of that disaster.

Early in the year, certain letters were written to the members of the Committee, calling for their views on the definition for the following:

(1) Ruling Grade.
(2) Value of Distance.
(3) Rise and Fall.
(4) Curvature—Compensated and Uncompensated.

Answers were received from a number of the members of the Committee, but after giving the subject further consideration, we do not feel that the time is ripe to establish a definition.

It is felt, that in order to be of definite value, the work of the Committee should be performed by men who can give up their time to investigations, and with that in view, your Chairman has requested that the work of the Committee on Economics of Railway Location be performed under the direction of the present Chairman, or of someone who shall be selected in his place, by a force of men who can give their undivided attention to the work for a space of six months, at least. These men will report to the Committee as a whole, and either revise their work in accordance with the criticism of the Committee, or secure the approval of the Committee, if the work is suitable. Your Chairman has, therefore, asked the Board of Direction to furnish authority and funds to conduct the work in that manner.

The work of the Committee in the future must necessarily involve the analysis of a great many figures, the detailed working out of examples, the construction of many drawings, profiles, etc., and a great deal of figuring.

It is felt that if this work was done by men who could devote their entire time to it, results of value to the railroad profession at large could be accomplished. To do the work in any other way must necessarily mean slow progress and, possibly, inaccurate conclusions.

It is therefore recommended that the sum of $400.00 per month for about six months be appropriated to employ:

1 man at	$200.00	per month
1 " "	125.00	" "
1 " "	75.00	" "

This force should report directly to the Chairman, who will submit the results to the Committee as a whole for their approval, and if approved, to the Association.

It is our understanding that this matter is now before the Board of Direction.

Respectfully submitted,

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION.

MINORITY REPORT.

To the Members of the American Railway Engineering Association:

We do not think this a good time to ask for an appropriation. Should such be made, however, salaried employes should work under the general directions of the Committee through its Chairman; but in no case should they be employed until sufficient data is on hand ready for analysis.

It has been our opinion, and is now, that this year's work should have been a continuation of the investigations of last year—an analysis of maintenance expenses to determine the proportionate costs of passenger and freight tonnage, and the relative damage to track per ton of engine and cars. Also, that one member should have been assigned to the study of the locomotive superheater so as to provide suitable corrections for tables 2 and 4 on pp. 429 and 431 of the Manual.

Last year the attempt was made to divide the expense of maintenance between passenger and freight tonnage, using a multiple (two) for passenger tons. Because this multiple was rejected by the Association as not proven does not minimize the importance of securing information on the subject. As to the necessity for some such apportionment of expense, we may quote the United States Supreme Court decision in the Minnesota rate case as follows (see Railway Age Gazette, June 20, 1913, page 1541):

"There should be assigned to each business that proportion of the total value of the property which will correspond to the extent of its employment in that business. It is said that this is extremely difficult; in particular, because of the necessity for making a division between the passenger and freight business, and the obvious lack of correspondence between ton-miles and passenger-miles. It does not appear, however, that these are the only units available for such a division; and it would seem that, after assigning to the passenger and freight departments respectively, the property exclusively used in each, comparable use-units might be found which would afford the basis for a reasonable division with respect to property used in common."

The question of damage to track of some of the present high locomotives is also a very live one.

We do not, therefore, concur in the report of the Chairman and other members; and recommend that for the ensuing year investigations be continued along the lines indicated in 1913, "report to determine the relative expense of maintenance due to passenger, freight and engine tonnage;" and that circulars "A" and "B," prepared by the former Chairman (forming an appendix to this report), be sent out for securing the desired information.

Respectfully submitted,

C. P. HOWARD.
E. C. SCHMIDT.

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION.

CIRCULAR "A."

NOTE.—Freight tracks will be designated as "Low Speed" and passenger as "High Speed" to include high-speed freight service operated over them.

Operating Data.

(1) Average gross tons per annum per mile of main track:

	Locomotives.	Bal. of Train.	Total Tons.
Low-speed tracks	———	———	———
High-speed tracks	———	———	———

(2) Average running velocity of trains:

Low speed ....Miles per Hour
High speed ....Miles per Hour

(3) Average curvature:

	Degrees per Mile.	Per Cent. of Line.
Low-speed tracks	———	———
High-speed tracks	———	———

Maintenance of Way and Structure Accounts.

NOTE.—Give average costs (or unit data) per track mile per annum in the answers:

(4) Account 1. Superintendence:

	Expense per Mile.
Low-speed tracks	———
High-speed tracks	———
Sidetracks	———

(5) Account 2. Ballast per mile:

	Cost.	Cu. Yds. per Annum.
Low-speed tracks	———	———
High-speed tracks	———	———
Sidetracks	———	———

(6) Account 3. Ties per mile:

	Cost.	No. per Annum.
Low-speed tracks	———	———
High-speed tracks	———	———
Sidetracks	———	———

(7) Account 4. Rails per mile:

	Cost.	Tons per Annum.
Low-speed tracks	———	———
High-speed tracks	———	———
Sidetracks	———	———

(8) Account 5. Other track material per mile:

	Cost.
Low-speed tracks	———
High-speed tracks	———
Sidetracks	———

(9) Account 6. Roadway and track per mile:

	Cost.
Low-speed tracks	———
High-speed tracks	———
Sidetracks	———

(10) Account 9. Bridges and culverts per mile:

	Cost.
Low-speed tracks	———
High-speed tracks	———

(11) Account 10. Over and undergrade crossings per mile:

	Cost.
Low-speed tracks	———
High-speed tracks	———

(12) Account 13. (Block signals only):
Cost per main track mile.................................... ———

(13) Account 18. Tools and supplies per mile:

	Cost.
Low-speed tracks	———
High-speed tracks	———
Sidetracks	———

(14) Account 16. Buildings:
Cost per main track mile.................................... ———

Give an estimate of the proportion of this that should be charged to high-speed or passenger service for the volume of traffic shown under Question 1, ———— per cent.

Chicago, Ill., April 8, 1913.

COMMITTEE ON ECONOMICS OF RAILWAY LOCATION

CIRCULAR "B."

Maintenance of Equipment.

NOTE.—Statistics received from certain roads indicate that repairs of locomotives vary more nearly with the horsepower hour work done than to the locomotive mile.

Answers to the following will assist in establishing a rational unit for analyzing accounts Nos. 25, 26 and 27. The figures may be from the average of the entire road and can be mostly obtained from data compiled for annual reports to Interstate Commerce Commission.

(1) Per cent. of total locomotive mileage.

Freight locomotives	————
Passenger locomotives	————
Switch locomotives	————

(2) Average per locomotive:

	Freight	Passenger	Switch
Tons weight excl. tender...........	———	———	———
Tons weight incl. tender............	———	———	———
Nominal tractive power	———	———	———
Average velocity operated (miles per hour) when in service.........	———	———	———

(3) Average cost per 1,000 locomotive miles for following:

	Freight	Passenger	Switch	All Classes
Account 25 repairs	———	———	———	———
Account 26 renewals	———	———	———	———
Account 27 depreciation	———	———	———	———

(If statistics are not kept separating these accounts by class of service, give costs per 1,000 locomotive miles for all classes.)

Conducting Transportation.

(4) Average of following items:

	Freight	Passenger	Switch
Costs per 100 loco. miles enginemen.			
Enginehouse expenses			
Fuel			
Lubricants			
Other supplies			
Pounds of coal used per loco. mile..			

(5) Costs per 100 train miles:

	Freight	Passenger
Road trainmen		
Train supplies and expenses..................		

(6) Cost per main track mile for operation of:

Block signals	
Type signals used	

Chicago, Ill., April 8, 1913.

REPORT OF SPECIAL COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

W. G. Atwood, *Chairman;*
C. A. Wilson, *Vice-Chairman;*
C. Frank Allen,
E. H. Lee,
John P. Congdon,
C. A. Paquette,
Thos. Earle,
H. C. Phillips,
J. C. Irwin,
J. H. Roach,
R. G. Kenly,
H. A. Woods,

Committee.

To the Members of the American Railway Engineering Association:

Your Special Committee on Uniform General Contract Forms begs to submit the following report.

We were instructed to continue the study of the contract form and to prepare forms for proposal blanks and for bonds.

A large portion of the work was carried on by correspondence and two meetings were held, one on November 7, 1913, at the House of the American Society of Civil Engineers, at which there were present Wm. G. Atwood, Chairman; C. A. Wilson, Vice-Chairman, and Messrs. Irwin, Allen, Earle, Roach and Paquette. A second meeting was held at the same place on January 24, at which there were present Wm. G. Atwood, Chairman, and Messrs. Irwin, Earle and Lee. At the latter meeting there was also present a committee representing the Surety Association of America, consisting of Messrs. Henry C. Wilcox, Vice-President, American Surety Company; Leonard Damann, Vice-President, National Surety Company; E. W. Briggs, Vice-President, New England Casualty Company, and R. R. Gilkey, Secretary, Surety Association of America.

The Committee has received only two criticisms of the "Contract Form" adopted at the annual meeting in March, 1913, although we understand that the form has been put in use by a number of companies.

One suggestion, received from the Mobile & Ohio Railroad, the Committee felt could be cared for by a minor change in the form of printing, and arrangements were made with the Secretary for this change when additional copies of the contract are printed.

The Toledo & Ohio Central Railroad suggested a change in clause 15, "Indemnity," and the Committee wish to recommend the insertion of the words "losses and" in line 1, clause 15, after the word "against," making this clause read, "The Contractor shall indemnify and save harmless the Company from and against all losses and all claims, demands, etc."

The Committee presents herewith a form for Proposals and recommends its adoption.

The Committee has been unable to complete the form for "Construction Bond," and would therefore recommend that it be instructed to complete this form and furnish a copy to the Secretary. We would recommend that the Secretary be instructed to send this form to the senior officer of each road represented in the Association with a request that the Legal Departments of those roads criticize the form.

Respectfully submitted,

COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

Form of Proposal.

.................................., 191...

....the undersigned propose to furnish all the materials, superintendence, labor, equipment and transportation, except as otherwise specified, and to execute, construct and finish in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer..........

....

and agree to commence the work within............days after receipt of the notice of award of the contract, and to complete the work within ....days thereafter, in accordance with the terms, conditions, requirements and specifications covered by the request for proposals made by..

dated..for the following prices:

....

(Signed)..

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

W. A. Christian, *Chairman;*
M. C. Byers, *Vice-Chairman;*
W. S. Danes,
J. H. Milburn,
G. J. Graves,
O. K. Morgan,
G. D. Hill,
Frank Ringer,
Henry Lehn,
Guy Scott,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Records and Accounts respectfully submits herewith its annual report:

The Board of Direction assigned the following work to your Committee for the current year:

(1) Make a comprehensive study of the forms in the Manual, which were adopted a number of years ago, and bring forms up to date.

(2) Continue the study of the economical management of store supplies.

(3) Recommend feasible and useful sub-divisions of Interstate Commission Classification Account No. 6, with a view to securing uniformity of labor costs.

(4) Study the subject of reports required by National and State Railway Commissions.

Sub-Committees were appointed by the Chairman after consultation with the Vice-Chairman, as follows:

Sub-Committee A—G. D. Hill, Chairman; W. S. Danes, Guy Scott.

Sub-Committee B—G. J. Graves, Chairman; O. K. Morgan.

Sub-Committee C—Henry Lehn, Chairman; J. H. Milburn.

Sub-Committee D—W. A. Christian, Chairman; M. C. Byers and Frank Ringer.

The members of the Sub-Committees were selected in accordance with their geographical location, so that it would not render a hardship on the members to hold Sub-Committee meetings, which meetings were held at various times during the year and at places selected by the chairman of each Sub-Committee.

The General Committee met at the office of the Association in Chicago on February 10.

(1) REVISION OF MANUAL.

The following conclusions are submitted for adoption:

(1) Eliminate the Foreman's Diary (form M. W. 1101), for the reason that the information given on the form should be shown on the Time Rolls (forms M. W. 1104, 1105), a space in each being provided for the purpose.

(2) Amend heading of form M. W. 701, Bridge Department Tool Report, to read, "Maintenance of Way Department Tool Report."

(3) Form M. W. 2100 "Estimate for Track," to be made uniform with form M. W. 2201, "Estimate for Buildings, Bridges and Water Service," by revising form M. W. 2100 accordingly.

The forms pertaining to accounts might be changed somewhat, but your Committee is of the opinion that no changes made at this time would bring about a more general use of the blanks by railways, and furthermore, it seems to your Committee that the rules and regulations of the Interstate Commerce Commission and of the American Railway Accounting Officers' Association have virtually disposed of the subject, and removed it from the province of the American Railway Engineering Association. It is therefore recommended by your Committee that no changes be made in the forms for keeping accounts at this time so far as they appertain to the Maintenance of Way Department and that the future work of the Committee be confined to working jointly with committees of other associations, with the ultimate object of developing a series of forms and reports for the maintenance of way accounting system that would conform to the rulings and regulations of the Interstate Commerce Commission and be generally used by railways.

CONVENTIONAL SIGNS OR SYMBOLS.

In the Specifications for Maps and Profiles, prescribed by the Interstate Commerce Commission, to be furnished by railway companies under the Act of Congress providing for the physical valuation of railway properties, the Conventional Signs or Symbols of the American Railway Engineering Association have been specified to be used as far as they are applicable. To make these Conventional Signs or Symbols as complete and consistent as possible, your Committee has carefully revised those now in the Manual and submits herewith a revision of the symbols for approval.

(2) ECONOMICAL MANAGEMENT OF STORE SUPPLIES.

Your Committee, after careful study of the report made last year, which was received as information, has no additional recommendations to make, and resubmits the conclusions presented last year for adoption:

CONCLUSIONS.

(1) Classification of Material.—It is recommended that the details of classification should conform to those adopted by the Railway Storekeepers' Association.

(2) Stock Account.—The conclusion reached last year is fundamental. The detailed methods of keeping the accounts may be varied to fit the individual condition. Stock accounts can be kept, (a) by

ledger account; (b) by card system; (c) by personal inspection and estimation.

(3) ORGANIZATION.—The essential elements are as follows:

(a) Location.—The store should be located as closely as possible to the point of greatest consumption, so that the minimum force will be required, and delay to material between the store and its destination may be reduced to a minimum. Usually this is at a point where equipment is maintained.

(b) Force.—The force required is dependent almost entirely on the character and volume of material issued and on local conditions. As the prompt and efficient handling of material and tools has a vital effect on the economical operation and maintenance of the railway, the force in the storeroom should be large enough to bring about this result.

(c) Position in Organization.—The consumption of supplies being greatest in maintenance of way and equipment, the Storekeeper should be closely associated with the heads of these departments. It is the opinion the the Committee that this can best be accomplished by having the Storekeeper, Engineer Maintenance of Way and the Master Mechanic report to the same officer. In a divisional organization this would place the Division Storekeeper under the Superintendent, and the General Storekeeper under the General Manager or Vice-President in charge of operation.

(d) Mechanical Equipment.—Cost of unloading, storing and loading material depends solely upon the volume of business done by each store, and such appliances as will reduce this cost to a minimum are recommended.

(3) SUB-DIVISIONS OF I. C. C. CLASSIFICATION ACCOUNT NO. 6.

The Interstate Commerce Commission, in their Classification of Operating Expenses, effective July 1, 1907, and supplements thereto, include in the maintenance of way accounts primary account No. 6—Roadway and Track. This account includes about one-third of the total charges for material and labor in the maintenance of way and structures accounts, and includes practically all of the labor performed by section and extra gangs chargeable to the maintenance of way and structures operating expenses; it seems therefore desirable to provide sub-divisions of this primary account in order to analyze operating expenses and assist in securing uniformity of labor costs.

The Interstate Commerce Commission does not specify as to the number of sub-divisions of this account, provided the account is charged with all elements of expense that the classification indicates should be charged to it. Accordingly, any sub-division made would be purely a company matter, and the Committee questions, if the Accounting Department is interested; that is to say, they would not require or ask it to be divided. That being the case, we are forced to conclude that the sub-

The Interstate Commerce Commission does not specify as to the number of sub-divisions of this account, provided it is charged with all elements of expense that the classification requires. Accordingly, any sub-division made would be purely a company matter, and the Committee questions if the Accounting Department is interested; that is to say, they would not require that it be divided. Assuming this to be the case, we conclude that the sub-division is for the use of the officer in charge of the maintenance of roadway and structures, in order that he may

(a) Determine the efficiency of section gangs;
(b) Analyze expenses;
(c) Effect economies.

By reference to the report of the Committee, contained in Vol. 14, pp. 1015-1017, it will be noted that this account is divided into nine sub-divisions, corresponding to the headings of the 13 divisions of the Interstate Commerce Commission classification. The Interstate Commerce Commission's 13 divisions were condensed to nine, and your Committee does not consider the number can be still further reduced, but suggests an additional one, No. "J," the heading to be "Work-Train Service;" i. e., rather than attempt to divide the work-train service between nine sub-divisions, it would be preferable to include it as one sub-division. The total of all sub-divisions should agree with the total charged to maintenance of way and structures account No. 6, including work-train service.

We would then have ten sub-divisions as follows:

(A) Track maintenance;
(B) Applying track material;
(C) Cutting weeds and general cleaning;
(D) Ditching and bank widening;
(E) Changing grades and alinement;
(F) Flood damage;
(G) Bank protection;
(H) Filling;
(I) Other care of roadway and track;
(J) Work-train service.

The application of the sub-divisions mentioned above to the 13 divisions of the Interstate Commerce Commission classification, would be as follows:

ROADWAY AND TRACK.

No. 1. Applying Ballast.

Pay of employes engaged in preparing roadbed for the reception of ballast; also pay of employes engaged in applying ballast after it has been prepared and unloaded. **B**

No. 2. Applying Ties.

Pay of employes engaged in unloading, distributing and renewing cross-, switch- and bridge-ties, head-blocks and railway crossing timbers, respacing ties and burning old ties. **B**

(Note.—Classify "respacing of ties" under "A.") **A**

No. 3. Applying Rails.

Pay of employes engaged in unloading, distributing, cutting, slotting, drilling and laying rails, adzing for new rails, gathering and loading old rails and adjusting, expansion and contraction. **B**

(Note.—Classify "adjusting, expansion and contraction" under "A.") **A**

No. 4. Applying Other Track Material.

Pay of employes engaged in applying rail braces, angle bars, rail joints, track bolts and spikes, nutlocks, anti-creepers, switches, switchstands, frogs, crossing frogs, tie plates, tie plugs and other miscellaneous track material not specified above. **B**

No. 5. Track Maintenance.

Pay of employes engaged in aligning, surfacing and gaging tracks, placing and removing track shims and tightening bolts and spikes in tracks. When a track is taken up, the labor expended therefor should be charged to this account, whether another track is laid to replace it or not. **A**

No. 6. Care of Roadbed.

Expenses of constructing and cleaning tile and open ditches; cost and expenses of placing and cleaning sewer pipes for drains (cost of sewer pipes laid under tracks should be charged to account "Bridges, Trestles and Culverts"); cost of material used and labor expended in sloping cuts, blasting rock, widening roadbeds, cuts, fills and embankments, filling borrow pits, removing slides, dangerous rocks and other similar obstructions; expenses of operating steam shovels, scrapers and ditchers while engaged in such work; **D**
also expenses of keeping tracks clear and repairing the sub-grade of tracks in cases of freshets or washouts and cost of boarding employes so engaged. Cost of labor building temporary tracks around slides and washouts and removing such tracks; cost of replacing rails, ties and ballast and repairing other damages caused by washouts to tracks proper or to the roadbed; **F**
cost of cutting, handling and placing sod; also landscape gardening and beautifying along roadway (except when chargeable to account "Buildings, Fixtures and Grounds"). **I**

No. 7. General Cleaning.

Pay of employes engaged in mowing right-of-way and burning grass and weeds; cost of operating weed burners, removing brush, grass and drift from right-of-way, and removing cinders dumped by passing trains, plowing fire-guards, removing weeds from and dressing ballast, cutting sod lines, removing dirt from track yards, cleaning streets used as roadways, **C**
and loading and handling track scrap. **B**

No. 8. Patrolling and Watching.

Pay of trackwalkers, track watchmen, patrolmen, employes while extinguishing fires on right-of-way and adjacent property, and watchmen at bad spots in tracks, slides and dangerous places. **I**
(For pay of bridge watchmen, see account, "Bridges, Trestles and Culverts;" for pay of street-crossing watchmen, see account, "Crossing Flagmen and Gatemen," and for pay of tunnel watchmen, see account, "Tunnels.") **G**

No. 9. Changing Alinement and Grades.

The proportion chargeable to operating expenses of cost of material used and labor expended in changing the alinement and reducing grades. **E**

No. 10. Bank Protection.

Cost of material used and labor expended in protecting banks by retaining walls, riprap, piling, piers, dikes or other means, and in **G**

constructing breakwaters and revetments and diverting the channels of streams to prevent cutting, washing or sliding of embankments.

No. 11. Filling.

Cost of material used and labor expended in filling bridges, trestles, culverts and cattle pits. **H**

No. 12. Other Expenses.

Cost of material used and labor expended in paving and improving streets used as roadway, and oiling roadbed; payments of assessments for street repairs, sewers, or other public improvements affecting roadway adjacent thereto, not chargeable to account "Buildings, Fixtures and Grounds"; expenses incident to track inspection, premiums in connection therewith, and any other roadway or track expenses not provided for elsewhere. **I**

No. 13. Train Service.

Pay of work-train, enginemen, trainmen and enginehousemen; cost of fuel, stores and other supplies (including cost of lubricating the equipment) for work-train locomotives and cars; cost of oil and wicking used in lanterns of work-train by enginemen and trainmen, while such employes and equipment are engaged in work pertaining to roadway and track. **J**

Numbers on left are the numbers of the Interstate Commerce Commission sub-divisions; letters on right indicate sub-divisions under which the whole or portions of the Interstate Commerce Commission subdivisions are classified.

(4) REPORTS REQUIRED BY FEDERAL AND STATE RAILWAY COMMISSIONS.

In the study of reports required by Federal and State Railway Commissions, the Committee, through the efforts of the Association Secretary, received from Canada and most of the states, blank forms on which steam railroads are required to report annually to the various Federal and State Commissions.

Many states submitted forms for power, light and heat company, street railway company, express company, telegraph and telephone company, and various other reports, which were not considered by the Committee.

Twenty-nine states and Canada use a form similar to that of the Interstate Commerce Commission. Ten states use different forms, but a comparison shows that they cover the same information called for in the Interstate Commerce Commission blanks.

Arkansas, Arizona, Delaware, Maine, North and South Carolina, Texas, Utah, New Mexico failed to reply to the Committee's request for blanks.

After careful study of the blanks prescribed by Federal and State Railway Commissions, your Committee reports progress and asks an expression of views and interpretation of the subject assigned, namely, "Study the subject of reports required by National and State Railway

Commissions"—whether it implies recommending changes in the forms prescribed by Federal and State Railway Commissions, or merely to make information available with reference to reports required by public service bodies.

PHYSICAL VALUATION OF RAILWAYS.

In accordance with the Act of Congress passed March 1, 1913, the Interstate Commerce Commission is charged with the duty of valuing the railway properties of the United States. Specifications for Maps and Profiles to be furnished by common carriers have been promulgated by the Interstate Commerce Commission under date of February 1, 1914. It has seemed desirable by your Committee to make this information available in our publications for the benefit of the members.

An abstract of the rules of the Railway Commission of Canada, relating to the requirements for maps and profiles, is also given for reference.

Respectfully submitted,

COMMITTEE ON RECORDS AND ACCOUNTS.

CONVENTIONAL SIGNS FOR USE ON TOPOGRAPHICAL, RIGHT-OF-WAY AND TRACK MAPS AND STRUCTURAL PLANS.

Title.	Present.	Proposed.

Hydrography (*shown in blue*).

Streams.

Springs and Sinks.

Lakes and Ponds.

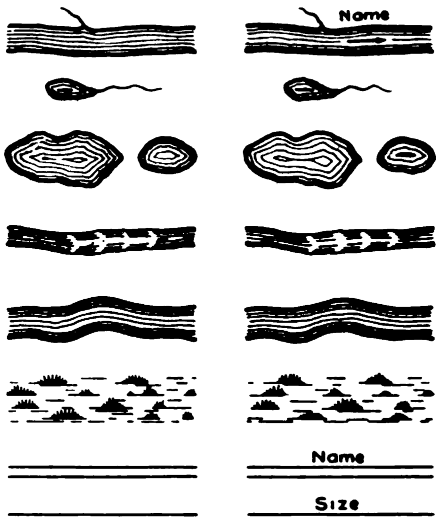
Falls and Rapids.

Water Line.

Marsh.

Canals.

Ditches.



Relief (*shown in blue*).

Contour System.

Sand.

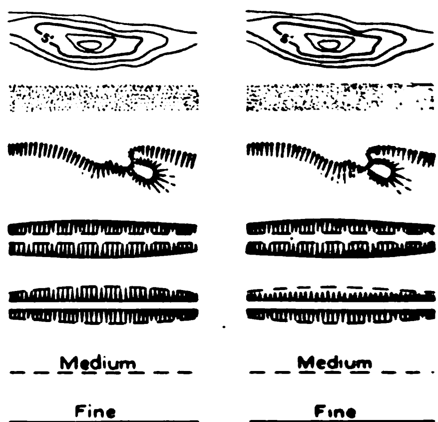
Cliffs.

Cuts.

Embankments.

Bottom of Slope.

Top of Slope.



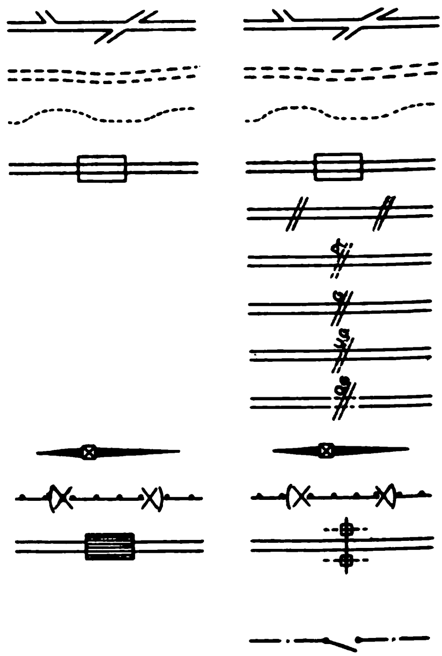
Title.	Present.	Proposed.
Boundary and Survey Lines (*Civil*).		
Political divisions, State, County or Township lines.	Bethel Twp.-Wayne Co.-Mich Posey Twp.-Adams Co.-Ind	Bethel Twp.-Wayne Co.-Mich Posey Twp.-Adams Co. Ind
Government Surveys, Base, Meridian Township, Section or Harbor Line.	Sec. 18. T. 12 N. R. 1 E. 3rd P.M. Sec. 13 T. 11 N. R. 1 E. 3rd P.M.	Sec. 18 T. 12 N. R. 1 E. 3rd P.M. Sec. 13 T. 11 N. R. 1 E. 3rd P.M.
Street, Block or other Property Line.		
Survey Lines.	Red Preliminary Location	Red Preliminary Location
Center Lines.	Original (Track or Section) Centre Line 19 If monumented, show Location and proper Symbol	Original (Track or Section) Centre Line 19 If monumented, show Location and proper Symbol
Company Property Line.		
Fence (on Street Line).	State kind and height	State kind and height
Fence (on Company Property Line).	State kind and height	State kind and height
*Stone Fence.		
*Board Fence.		Give Height
*Picket Fence.		Give Height
*Barb Wire Fence.		Give Height
*Rail Fence.		Give Height
*Worm Fence.		Give Height
*Woven Wire Fence.		Give Height
*Snow Shed.		Give Height
*Hedge.		
Cities.		
Villages.		
City Limits.		
Fire Limits.		

*Additions.

Title.	Present.	Proposed.

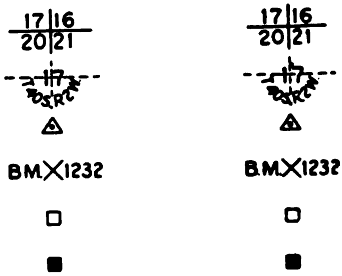
Highways and Crossings.

Title.	Present.	Proposed.
Public and Main Roads.		
Private and Secondary Roads.		
Trails.		
Road Crossings.		
*Street and Public Road Crossings.		
*Private Road Crossing.		
*Road Crossing at Grade.		
*Road Crossing Under Grade.		
*Road Crossing Overhead.		
Crossing Gate.		
Turnstile.		
Cattle Guards.		
*Farm Gate.		



Section Corners, Monuments, Etc.

Title.	Present.	Proposed.
Section Corner.	17 | 16 / 20 | 21	17 | 16 / 20 | 21
Section Center.		
Triangulation Station or Transit Point.		
Bench Mark.	BM×1232	BM×1232
Stone Monument.		
Iron Monument.		



*Additions.

Title.	Present.	Proposed.
	Mines.	
Tunnel.		
Shaft.		
Test Opening.		
Coal Outcrop.		
Mine in Operation.		
	***Railways (*Topographical Maps*).**	
Steam.		
Electric.		
Street Railways.		
	***Railway Tracks (*Track Maps*).**	
Railway track or old track to remain.		
Old track to be taken up.		
New tracks.	Red	Red
Future tracks.	Red	Red
Foreign tracks.	Color other than Red	Color other than Red
Alinement { 4° Curve to right. 2° Curve to left.		4° 2°
	***Track Fixtures.**	
Turnout and Switch Stand.		
Interlocked Switch.		
Derail.		
Bumping Post.		

*For Railway track and yard studies use single or double lines.

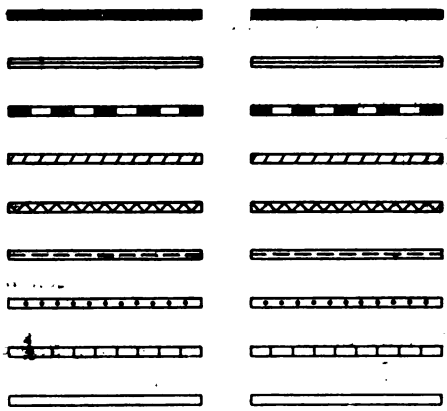
Title.	Present.	Proposed.
	Buildings.	
F Frame.	F	
B Brick.	B	
S Stone.	S	P Pass Station
C Concrete.	Character	F Frt. Station
Cor. I. Corrugated Iron.		PF Pass and Frt. Station
Use letters to indicate character.		
Platform or Driveway.	State Kind	Indicate Kind and Character
Turntable.		
Interlocking Tower.		
*Section Dwelling.		In Plan In Profile Indicate Kind of Material No. of Story and Rooms
*Coal Chute (Mechanical).		C S
*Coal Chute (Trestle).		C. S.
*Circular Engine House.		
*Rectangular Engine House.		State use and Character
*Telegraph Office in Station.		T
	Signs and Signals.	
Mile Post.	P. 16 B. 415	15 16
Section Post.	5 6	Sec. 5 6
Yard Limits.		
Highway Crossing Bell.		

*Additions.

Title.	Present.	Proposed.

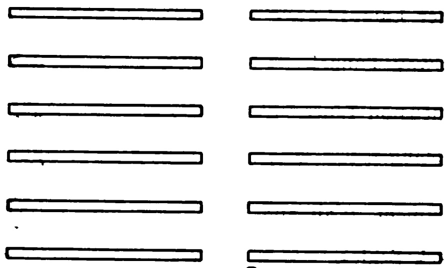
Ballast.

Broken Stone.
Slag.
Screenings.
Gravel.
Cinders.
Chats.
Sand.
Burnt Clay.
Earth.



Rail.

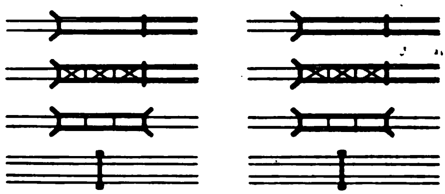
100-lb. Black.
90-lb. Red.
85-lb. Yellow.
80-lb. White.
75-lb. Green.
70-lb. Purple.



Rerolled Rail to be shown in broken line

***Bridges.**

Girder.
Truss.
Trestle.
Signal Bridge.

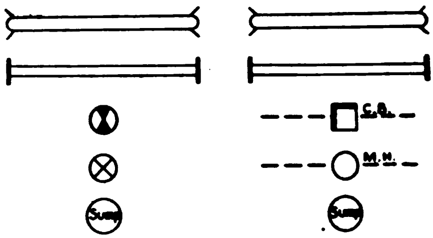


*For Railway track and yard studies use single or double lines.

Title. **Present.** **Proposed.**

Culverts, Sewers, Etc.

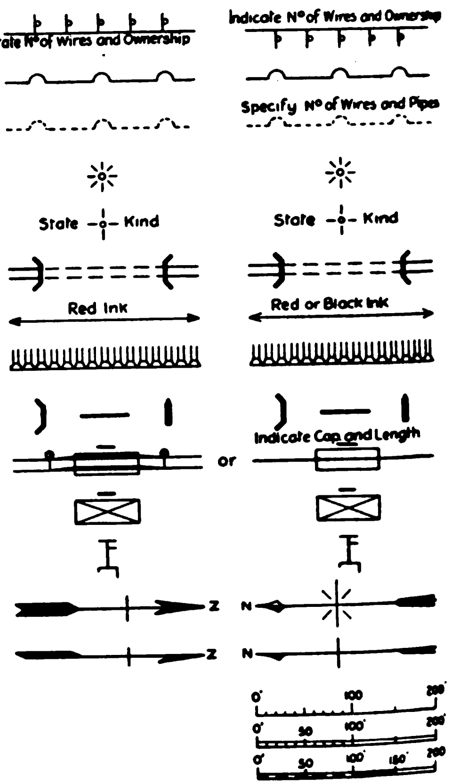
Masonry Arch or Flat-top Culvert.
Pipe or Wood Box Culverts or Drains; state kind and length, and kind of walls, if any.
Catch Basin.
Manhole.
Sump.



Miscellaneous.

Pole Wire Lines.
Switch or Signal Connecting Lines.
Wire Conduit.
Arc Lamp.
Other Lamps.
Railway Tunnel.
Dimension Line.
Cribbing.
Abutment, Wall and Pier.
Track Scales.
Wagon Scales.
Mail Crane.
True Meridian.
Magnetic Meridian.

*Scales.



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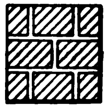
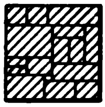
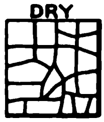
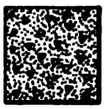
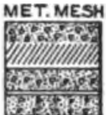
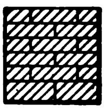
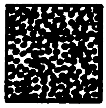
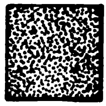
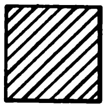
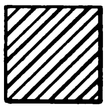
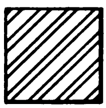
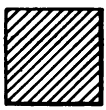
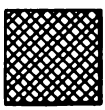
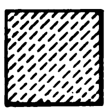
*Additions.

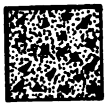
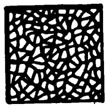
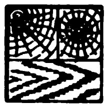
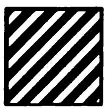
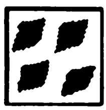
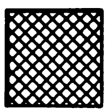
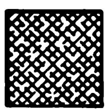
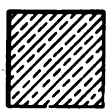
Title.	**Present.**	**Proposed.**
	Water Supply and Pipe Lines.	
Water Tank.		Give Character, Diam. & Ht... W. T.
Water Column.		
Track Pan.		
Company Water Pipe.		Give size
Other Water Pipe.		
Steam, Compressed Air or Gas.	State kind	Give size
Fire Hydrant.		H
Valve.		V.
Riser.		
Meter.		M
*Sewer or Drain.		Give size

*Additions.

Title.	Present.	Proposed.
Masonry.		
Rockfaced Ashlar.		
Dressed Ashlar.		
Uncoursed Ashlar.		
Rubble.	MORTAR 	
Rubble.	DRY 	No Change Recommended.
Plain Concrete.		
Reinforced Concrete.	MET. MESH  RODS OR BARS	
Brick.		
Geological Strata.		
Solid Rock.		
Seamy Rock.		

Title.		Present.	Proposed.
Earth.			No Change Recommended.
Gravel.			
Sand.			
	Metals.		
Wrought Steel.		 	
Cast Steel.			
Wrought Iron.			
Cast Iron.			
Malleable Iron.			
Copper.			

Miscellaneous.

Title.	Present.	Proposed.
Cinders.		No Change Recommended.
Crushed Rock.		
Water.		
Wood.		
Wool, Felt, Asbestos, Leather, etc.		
Mica, Rubber, Vulcanite, Fiber, etc.		
Glass.		
Comp. Metal, Lead, Babbitt, etc.		
Bronze.		
Brass.		

*Structural.

A—BRIDGE RIVETS.

	Shop. Field.
Two Full Heads.	
Countersunk and chipped, far side.	
Countersunk and chipped, near side.	
Countersunk and chipped, both sides.	

	Far Side. Near Side. Both Sides.
Countersunk and not chipped.	
Flattened to ¼-in. high for ½-in. and ⅝-in. rivets.	
Flattened to ⅜-in. high for ¾-in., ⅞-in. and 1-in. rivets.	

B—STRESSES.

Tension.	+
Compression.	—

*No change recommended.

SPECIFICATIONS FOR MAPS AND PROFILES.

AS PRESCRIBED BY THE INTERSTATE COMMERCE COMMISSION IN ACCORDANCE WITH SECTION 19A OF THE ACT TO REGULATE COMMERCE.

FIRST ISSUE—EFFECTIVE ON FEBRUARY 1, 1914.

Order.

AT A GENERAL SESSION OF THE INTERSTATE COMMERCE COMMISSION, HELD AT ITS OFFICE IN WASHINGTON, D. C., ON THE 12TH DAY OF JANUARY, A. D. 1914.

The subject of specifications for maps and profiles to be prescribed for and applied by steam railway carriers being under consideration, the following order was entered:

It is ordered, That the specifications for maps and profiles which are set out in printed form to be hereafter known as first issue, a copy of which is now before this Commission, be, and the same are hereby, approved; that a copy thereof, duly authenticated by the Secretary of the Commission, be filed in its archives, and a second copy thereof, in like manner authenticated, in the office of the division of valuation; and that each of said copies so authenticated and filed shall be deemed an original record thereof.

It is further ordered, That the said specifications for maps and profiles be, and the same are hereby, prescribed for the use of all steam railway carriers subject to the provisions of the act to regulate commerce, as amended, in the preparation of all maps and profiles which shall be required filed with this Commission in accordance with section 19a of the act to regulate commerce, that each and every carrier and each and every receiver or operating trustee of any such carrier be required to prepare and furnish to the Commission all maps and profiles in conformity therewith; and that a copy of the said first issue be sent to each and every such carrier and to each and every receiver or operating trustee of any such carrier.

It is further ordered, That every steam railway carrier prepare and furnish to the Commission complete maps and profiles of its property as it exists June 30, 1914, on or before February 1, 1915, or by such subsequent date as may be fixed by the Commission as a result of a hearing which will be given any carrier to show cause why said maps and profiles cannot be filed within such time limit.

It is further ordered, That maps and profiles of extensions and improvements or other changes made after June 30, 1914, shall be prepared and furnished to the Commission within six months after said extension and improvement or change has been placed in operation.

It is further ordered, That February 1, 1914, be, and is hereby fixed as the date on which the said first issue of the specifications for maps and profiles shall become effective.

By the Commission. GEORGE B. MCGINTY,
[SEAL.] *Secretary.*

INTRODUCTORY STATEMENT.

INTERSTATE COMMERCE COMMISSION,
Washington, January 12, 1914.

To Railway Carriers:

The accompanying specifications for maps and profiles required by the Interstate Commerce Commission under authority of section 19a of the act to regulate commerce prescribe standards which, from date of issue, will apply to all maps and profiles which shall finally be filed with the Commission in connection with the valuation of railway properties.

To enable the Commission to begin the valuation work promptly, the carriers shall furnish for initial use copies of those existing maps and profiles and other standard and special plans that will assist the Commission in its work. These existing maps, profiles and other plans shall be collected together by the carriers at their general engineering offices for inspection by the Commission, and copies of such maps, profiles and other plans which it determines useful for its purpose shall be furnished when requested.

Many standard and special plans of structures will be required by the Commission in connection with the valuation, from time to time, but the permanent filing of all such special records with the Commission is not contemplated at this time, and carriers will be required to preserve such plans at their general offices so as to be readily accessible to the Commission.

A copy of section 19a of the act to regulate commerce is included as Appendix A.

Should a question arise at any time in the minds of officers of carriers with regard to the correct interpretation of any portion of these specifications, such officials are invited to correspond with the Commission in order that uniformity may be secured in their application.

GEORGE B. MCGINTY,
Secretary.

SYNOPSIS.

SPECIFICATIONS FOR THE PREPARATION OF THE MAPS AND PROFILES WHICH SHALL BE FILED WITH THE INTERSTATE COMMERCE COMMISSION TO SUPPORT THE VALUATION OF PROPERTY OF RAILWAY CARRIERS.

I. GENERAL.

1. Intent.

In order that the Interstate Commerce Commission may investigate, ascertain, report and record the value of property of railway carriers as it now exists and as it hereafter may be extended, improved or changed, it is essential that certain maps and profiles shall be prepared by the carriers and filed with the Commission.

It is not the intent of the Commission to require the unnecessary construction of maps and profiles. All maps and profiles, both old and new, must be furnished upon sheets of the standard sizes and upon material of the kind specified, and they must be produced or reproduced by the process specified.

All new maps and profiles, whether covering new construction or old construction, must be strictly in accordance with these specifications.

Where maps and profiles already in existence contain, in the opinion of the Commission, the necessary information in such form that it is reasonably available, these will be accepted.

For the purpose of ascertaining to what extent their present maps are acceptable carriers may bring together at their principal engineering offices such maps and profiles as they desire to tender. Thereupon the Commission will at once examine the same and will indicate in writing what are acceptable in their present form and what changes or additions should be made in order to make others acceptable.

Except in case of existing maps and profiles accepted or modified as above, these specifications must be strictly followed.

II. MAPS AND PROFILES REQUIRED.

2. Classes and Titles.

Three general classes of drawings shall be made by the carriers and filed with the Commission, viz.:

(1) Right-of-Way and Track Map.

(2) Station Maps.

 (*a*) Maps showing all lands, separately from improvements, when this is necessary for clearness.

 (*b*) Maps showing tracks and structures and external land boundaries.

(3) Profile.

3. Description and Purpose.

The Right-of-Way and Track Map shall be a true horizontal projection of the right of way, tracks and other structures, platted continuously between district or terminal points.

The Station Maps shall be a supplement to the above for terminals and other locations where the property of carriers is so extensive and complicated that it cannot be clearly shown on the Right-of-Way and Track Map. The Station Maps shall be made in two separate sets, one showing details as to lands and the other the tracks, structures and external land boundaries, except that where practicable to show clearly on one map all information specified hereinafter, this may be done.

The profile shall be a vertical, sectional view on center line of track (or other railway base line) on an exaggerated vertical scale, and shall show the features of the railway track substructure and superstructure, which can best be indicated in vertical projection; also such other detail information as is hereinafter more fully set forth.

III. MATERIALS.

4. Cloth.

All maps and profiles shall be made by hand or by a lithographic process, approved by the Commission, on the best grade of tracing cloth (Imperial or its equal).

5. Ink.

The ink used for making maps and profiles shall be the best grade, black, waterproof, and permanent india or printer's ink. The profile ruling shall be printed in orange (colored) ink where hand tracings are furnished.

IV. FORM OF MAPS AND PROFILES.

6. Size of Sheets.

The Right-of-Way and Track Map shall be made in sheets 24 by 56 inches. A plain, single-line border shall be drawn on each sheet, dimensions inside of which shall be 23 by 55 inches.

The Station Maps shall be made in sheets 24 by 56 inches, with border line as above. When more than one sheet is required to show a station property, the plat shall be made upon "matched marked" sheets in such manner as to require a minimum number.

The profile shall be made in sheets 12 by 56 inches with border. The size inside of border lines shall be 10 by 55 inches.

7. Scales.

The Right-of-Way and Track Map shall be made on a scale of 1 inch equals 400 feet, or 1 inch equals 200 feet.

The Station Maps shall be made on a scale of 1 inch equals 100 feet, or in complicated situations 1 inch equals 50 feet.

The Profile shall be made on standard plate A, and on scales of: Vertical, 1 inch equals 20 feet; horizontal, 1 inch equals 400 feet.

8. Symbols.

The symbols used on all maps and profiles shall be the standards recommended by the American Railway Engineering Association, in so far as they may be applicable.

9. Lettering.

All lettering on maps and profiles shall be in plain, simple style.

10. Arrangement of Data.

The Right-of-Way and Track Map sheets shall be made with the zero or lowest number station at the left side of each sheet and shall be platted continuously from left to right. Where the use of this method would involve the abandonment of established survey station numbers of a railway, the platting may be done in such a way as to preserve them, provided the maps or profiles for any given main line or branch are continuous in same direction between termini of main line or branch. The general direction of the center line of track shall be as nearly as possible parallel to and half way between the long sides of sheets, so that the maximum space each side of platted right-of-way lines may be available for showing adjacent topography and property lines and for making notes as to physical property. The maximum length of main roadway represented on any one sheet (between "match marks") shall be 4 miles,

if scale is 1 inch equals 400 feet, or 2 miles if scale is 1 inch equals 200 feet.

The Station Maps shall be made as prescribed above for Right-of-Way and Track Maps.

The Profile shall be made so that any serially numbered sheet shall cover the same portion of the railway as the like serially numbered sheet or sheets of the Right-of-Way and Track Map. Platting shall be done as specified above. The 2½-inch space immediately above the lower border line shall be used for track alignment and topographic data. The remaining 7½-inch space shall be used for platting the profile in such a way as to most economically utilize the space.

11. Cardinal Points.

On all Right-of-Way and Track Map sheets and Station Maps an arrow showing the true north and south line (as nearly as can be ascertained from existing records) shall be placed. This arrow shall be not less than 3 inches in length and shall have the letter "N" marked at its north end.

12. Indexing.

For each series of Right-of-Way and Track Maps there shall be made a small skeleton index map on a scale of not less than one-fourth inch equals 1 mile. Where practicable this index map may be placed on any vacant space of the first sheet of a series, and where made on a separate sheet it shall be 24 by 56 inches. This index map shall show by outline with file numbers therein the sheets of a series, the name of main line division or branch line, the principal cities or towns, and the beginning and ending station numbers of series, and any other information carrier may elect to place thereon.

All Right-of-Way and Track Map sheets and Profile sheets shall be numbered serially, beginning with sheet 1. The sheets representing valuation sections shall form separate series and the valuation sections shall be numbered serially with the letter "V" preceding the number. The letter "P" shall precede the serial number or numbers on the profile sheets. Index numbers shall be in lower right-hand corner of the sheet and inclosed in plain, single-line circle 1 inch in diameter. Valuation numbers shall be in the upper half of circle and sheet number below with a straight line between.

The Station Maps shall be given the same serial number preceded by the letter "S" as the sheet of the Right-of-Way and Track Map which they supplement.

In case a Right-of-Way and Track Map sheet is supplemented by more than one Station Map, a subscript letter should be used after the number, e. g., S 32a, S 32b, etc., where land and track features are combined; S-L 32a, etc., where land only is shown; and S-T 32a, etc., where track features only are shown.

On the Right-of-Way and Track Map sheets references to all Station Maps shall be shown by outlining limits of Station Maps and giving the number of the Station Map sheets.

The carrier's file number shall also be placed on all map and profile sheets in the lower left-hand corner.

13. Title.

The title shall be placed as near the lower right-hand corner as practicable. The following information shall be given therein:

(1) Class.
Right-of-Way and Track Map.
Station Map.
Profile.

(2) Corporate name of the railway.
(3) Name of operating company.
(4) Name of railway division or branch line.
(5) Beginning and ending survey station numbers on sheet.
(6) Scale or scales.
(7) Date as of which maps or profiles represent the facts shown thereon.
(8) Office from which issued.

14. Certification.

A certificate as to the correctness of all maps and profiles shall be printed and executed on the first sheet of each series, and each of the other sheets of the same series shall be identified as a part thereof. The certificate on the first sheet of each series shall be placed as near the title as practicable and shall be of the following form:

State of ....
County of ....
I, the undersigned, officer of the ....
(Name or railway company.)
do hereby certify that this is a correct ....
(Map or profile.)
in a series of .... sheets, of said railway from survey station ....to survey station ....
(Main line, division, or branch.)
.... State of ....
prepared from the records of said company.

....
Engineer.

Correct:

....
(Name of officer authorized to certify records.)

Subscribed and sworn to before me this ...... day of ....

....
Notary public in and for the
County of ....
State of ....

My commission expires ....

The identification on the other sheets of a series shall be of the following form and placed as near the title as practicable:

Sheet No. ...... of .... of ....
(Series.) (Railway, main line or branch.)
from survey station .... to survey station ....

....
Engineer.

V. DATA REQUIRED.

15. On the Right-of-Way and Track Map.

On the Right-of-Way and Track Map shall be shown the following data:

(*a*) *Boundary Lines of All Right of Way.*—The term "right of way" as herein used includes all lands owned or used for purposes of a common carrier, no matter how acquired.

Show: Width of right of way, in figures, at each end of the sheet and at points where a change of width occurs, with station and plus of such points; boundary lines and dimensions of each separate tract acquired; a schedule of deed, custodian's number, the name of grantor and grantee, kind of instrument, date and book and page where recorded. Each tract of land shall be given a serial number and listed

serially in the schedule. The schedule shall also include reference to leases to the company, franchises, ordinances, grants, and all other methods of acquisition.

(*b*) *Boundary Lines of Detached Lands.*—Where same can be shown clearly. The term "detached lands" as herein used includes:

(1) Lands owned or used for purposes of a common carrier, but not adjoining or connecting with other lands of the carrier.

(2) Lands owned and not used for purposes of a common carrier, either adjoining or disconnected from other property owned by the carrier.

Show: Boundary lines and dimensions; distance and bearing from some point on the boundary line to some established point or permanent land corner, where practicable, and separately on the schedule above, the lands not used for purposes of a common carrier.

(*c*) *Intersecting Property Lines of Adjacent Landowners.*—Where the information is in the possession of the carrier show: The property lines of adjacent landowners, the station and plus of important intersections of property lines with center line of railway or other railway base line, and the names of owners of the land adjacent to the right of way.

(*d*) *Intersecting Divisional Land Lines.*—Show: Section, township, county, state, city, town, village or other governmental lines, with names or designations; the width and names of streets and highways which intersect the right of way; and the station and plus at all such points of crossing or intersections with center line of railway or other railway base line.

(*e*) *Division and Subdivision of Lands Beyond the Limits of the Right of Way.*—Where the information is in the possession of carrier show: The section and quarter-section lines for a maximum distance of 1 mile on each side of the center or base line of railway where the land has been subdivided into townships and sections; such data as to divisions, tracts, streets, alleys, blocks and lots, where the land has been divided in some other way than by sections; the distance, where known, from railway base line to permanent land corners or monuments; and the base line from which the railway's lands were located (center line of first, second, third or fourth main track or other base line).

(*f*) *Alinement and Tracks.*—Show: The center line of each main and sidetrack when such tracks are outside the limits covered by the Station Maps and center line of each main track, also inside Station Map limits; the length, in figures, of all sidetracks from point of switch to point of switch, or point of switch to end of track; all other railways, crossed or connecting, and state if crossing is over or under grade, and give name of owner of such tracks; survey station number at even 1,000 scale-feet intervals, and station and plus at points of all main line switches at points of curves and tangents and at beginning and ending points on each sheet; the degree and central angle of curves; and joint tracks and ownership thereof.

(*g*) *Improvements.*—Show: Station and office buildings, shops, engine houses, fuel stations, water stations, etc. (owned by the carrier), in general outline, where it can be done clearly. Also indicate conventionally: Bridges, trestles, culverts, tunnels, retaining walls, cattle guards, mileposts, signal bridges and ground masts, fences by note only, and other principal railway structures owned by the carrier, with general data as to dimensions; and, where practicable, pipe lines, sewers, underground conduits, paving, curbing or similar works located on the right of way of the carrier or adjoining and owned by the carrier in whole or in part. Give station and plus to all important structures which are outlined above.

(*h*) *Topographical Features.*—Show: Rivers, creeks, watercourses, highway crossings, etc. Give names, where known, and when highway crossings are over or under grade, so state.

16. On Station Maps.

The purpose of the large scale Station Maps is to permit the showing of improvements in more detail than is practicable on the right-of-way and track map.

Where the station property to be mapped is extensive and complicated, it shall be delineated on two separate maps.

(1) Shall show all data relating to ownership of lands.

(2) Shall show all tracks and structures and external land boundaries.

Where practicable, without sacrificing the clearness of the map, the two may be combined into one map.

Show all information set forth under items (*a*) to (*h*), inclusive, of section No. 15, when inside of Station Map limits, and all other surface and subsurface improvements owned by the carrier and not hereinbefore noted, as far as may be practicable.

Tracks shall be represented on Station Maps either by center lines or by rail lines.

17. On Profile.

The following data shall be placed on all Profiles:

(*a*) *Roadway.*—Show: The vertical projection of the original ground surface on center line of railway; present grade line (top of the roadbed subgrade); rates of grade; elevations (sea-level datum) at all points of change of grade, at each end of sheets and where profile is "broken," at 50-foot (scale) intervals; and the station and plus to points of change of grade and station numbers at each 1,000-foot (scale) interval near lower border of sheet.

(*b*) *Structures.*—Show: Bridges, trestles, culverts, retaining walls, tunnels, and other roadbed structures in vertical projection, stating the kind and general dimensions by figures; average depth of penetration of piling in each bent of trestles, or under other structures, by vertical projection; character of, and depth of foundation bed of masonry structures by vertical projection; reference to railway file numbers of the detail standard or special plans by which the structures were built; existing mile posts; and the station and plus of each of the above indicated improvements.

(*c*) *Quantities.*—Profiles of railways built after the date of issue of these specifications shall show for each mile a summary of construction quantities to subgrade, including roadway, bridges and culverts. Profiles of railways built before the issue of these specifications may show, at the option of the carrier, similar quantities in the same summary form.

The summary of quantities shall be in detail, according to the standard classification of units used by each carrier.

(*d*) *Alinement and Track.*—Show: On the lower 2½ by 55-inch space of the profile sheet, the center line of each main track, developed into straight line or lines, with alinement notes of curves stated in figures; the station and plus at points of curves and tangents; and other data, such as passing tracks, depot buildings, water and fuel stations, highway crossings, railway crossings, and important watercourses that will assist in interpreting the profile. For platting transversely a scale of 1 inch equals 200 feet shall be used.

Appendix A.

[PUBLIC—NO. 400.]

[H. R. 22593.]

An Act to amend an Act entitled "An Act to regulate commerce," approved February fourth, eighteen hundred and eighty-seven, and all Acts amendatory thereof by providing for a valuation of the several classes of property of carriers subject thereto and securing information concerning their stocks, bonds, and other securities.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Act entitled, "An Act to regulate commerce," approved February fourth, eighteen hundred and eighty-seven, as amended, be further amended by adding thereto a new section, to be known as section nineteen a, and to read as follows:

"SEC. 19a. That the Commission shall, as hereinafter provided, investigate, ascertain and report the value of all the property owned or used by every common carrier subject to the provisions of this Act. To enable the Commission to make such investigation and report, it is authorized to employ such experts and other assistants as may be necessary. The Commission may appoint examiners who shall have power to administer oaths, examine witnesses, and take testimony. The Commission shall make an inventory which shall list the property of every common carrier subject to the provisions of this Act in detail, and show the value thereof as hereinafter provided, and shall classify the physical property, as nearly as practicable, in conformity with the classification of expenditures for road and equipment, as prescribed by the Interstate Commerce Commission.

"First. In such investigation said Commission shall ascertain and report in detail as to each piece of property owned or used by said common carrier for its purposes as a common carrier, the original cost to date, the cost of reproduction new, the cost of reproduction less depreciation, and and an analysis of the methods by which these several costs are obtained, and the reason for their differences, if any. The Commission shall in like manner ascertain and report separately other values, and elements of value, if any, of the property of such common carrier, and an analysis of the methods of valuation employed, and of the reasons for any differences between any such value, and each of the foregoing cost values.

"Second. Such investigation and report shall state in detail and separately from improvements the original cost of all lands, rights of way, and terminals owned or used for the purposes of a common carrier, and ascertained as of the time of dedication to public use, and the present value of the same, and separately the original and present cost of condemnation and damages or of purchase in excess of such original cost or present value.

"Third. Such investigation and report shall show separately the property held for purposes other than those of a common carrier, and the original cost and present value of the same, together with an analysis of the methods of valuation employed.

"Fourth. In ascertaining the original cost to date of the property of such common carrier the Commission, in addition to such other elements as it may deem necessary, shall investigate and report upon the history and organization of the present and of any previous corporation operating such property; upon any increases or decreases of stocks, bonds or other securities, in any reorganization; upon moneys received by any such corporation by reason of any issues of stocks, bonds or other securi-

ties; upon the syndicating, banking and other financial arrangements under which such issues were made and the expense thereof; and upon the net and gross earnings of such corporations; and shall also ascertain and report in such detail as may be determined by the Commission upon the expenditure of all moneys and the purposes for which the same were expended.

"Fifth. The Commission shall ascertain and report the amount and value of any aid, gift, grant of right of way or donation made to any such common carrier, or to any previous corporation operating such property, by the Government of the United States or by any State, county, or municipal government, or by individuals, associations or corporations; and it shall also ascertain and report the grants of land to any such common carrier, or any previous corporation operating such property, by the government of the United States or by any State, county or municipal government, and the amount of money derived from the sale of any portion of such grants and the value of the unsold portion thereof at the time acquired and at the present time, also, the amount and value of any concession and allowance made by such common carrier to the Government of the United States, or to any State, county or municipal government in consideration of such aid, gift, grant or donation.

"Except as herein otherwise provided, the Commission shall have power to prescribe the method of procedure to be followed in the conduct of the investigation, the form in which the results of the valuation shall be submitted, and the classification of the elements that constitute the ascertained value, and such investigation shall show the value of the property of every common carrier as a whole and separately the value of its property in each of the several States and Territories and the District of Columbia, classified and in detail as herein required.

"Such investigation shall be commenced within sixty days after the approval of this Act and shall be prosecuted with diligence and thoroughness, and the result thereof reported to Congress at the beginning of each regular session thereafter until completed.

"Every common carrier subject to the provisions of this Act shall furnish to the Commission or its agents from time to time and as the Commission may require, maps, profiles, contracts, reports of engineers, and any other documents, records and papers or copies of any or all of the same, in aid of such investigation and determination of the value of the property of said common carrier, and shall grant to all agents of the Commission free access to its right of way, its property and its accounts, records and memoranda whenever and wherever requested by any such duly authorized agent, and every common carrier is hereby directed and required to co-operate with and aid the Commission in the work of the valuation of its property in such further particulars and to such extent as the Commission may require and direct, and all rules and regulations made by the Commission for the purpose of administering the provisions of this section and section twenty of this Act shall have the full force and effect of law. Unless otherwise ordered by the Commission, with the reasons therefor, the records and data of the Commission shall be open to the inspection and examination of the public.

"Upon the completion of the valuation herein provided for the Commission shall thereafter in like manner keep itself informed of all extensions and improvements or other changes in the condition and value of the property of all common carriers, and shall ascertain the value thereof, and shall from time to time, revise and correct its valuations, showing such revision and correction classified and as a whole and separately in each of the several States and Territories and the District of Columbia, which valuations, both original and corrected, shall be tentative

valuations and shall be reported to Congress at the beginning of each regular session.

"To enable the Commission to make such changes and corrections in its valuations of each class of property, every common carrier subject to the provisions of this Act shall make such reports and furnish such information as the Commission may require.

"Whenever the Commission shall have completed the tentative valuation of the property of any common carrier, as herein directed, and before such valuation shall become final, the Commission shall give notice by registered letter to the said carrier, the Attorney-General of the United States, the governor of any State in which the property so valued is located, and to such additional parties as the Commission may prescribe, stating the valuation placed upon the several classes of property of said carrier, and shall allow thirty days in which to file a protest of the same with the Commission. If no protest is filed within thirty days, said valuation shall become final as of the date thereof.

"If notice of protest is filed the Commission shall fix a time for hearing the same, and shall proceed as promptly as may be to hear and consider any matter relative and material thereto which may be presented in support of any such protest so filed as aforesaid. If after hearing any protest of such tentative valuation under the provisions of this Act the Commission shall be of the opinion that its valuation should not become final, it shall make such changes as may be necessary, and shall issue an order making such corrected tentative valuation final as of the date thereof. All final valuations by the Commission and the classification thereof shall be published and shall be prima facie evidence of the value of the property in all proceedings under the Act to regulate commerce as of the date of the fixing thereof, and in all judicial proceedings for the enforcement of the Act approved February fourth, eighteen hundred and eighty-seven, commonly known as "the Act to regulate commerce," and the various Acts amendatory thereof, and in all judicial proceedings brought to enjoin, set aside, annul or suspend, in whole or in part, any order of the Interstate Commerce Commission.

"If upon the trial of any action involving a final value fixed by the Commission, evidence shall be introduced regarding such value which is found by the court to be different from that offered upon the hearing before the Commission, or additional thereto and substantially affecting said value, the court, before proceeding to render judgment, shall transmit a copy of such evidence to the Commission, and shall stay further proceedings in said action for such time as the court shall determine from the date of such transmission. Upon the receipt of such evidence the Commission shall consider the same and may fix a final value different from the one fixed in the first instance, and may alter, modify, amend or rescind any order which it has made involving said final value, and shall report its action thereon to said court within the time fixed by the court. If the Commission shall alter, modify or amend its order, such altered, modified, or amended order shall take the place of the original order complained of and judgment shall be rendered thereon as though made by the Commission in the first instance. If the original order shall not be rescinded or changed by the Commission, judgment shall be rendered upon such original order.

"The provisions of this section shall apply to receivers of carriers and operating trustees. In case of failure or refusal on the part of any carrier, receiver or trustee to comply with all the requirements of this section and in the manner prescribed by the Commission, such carrier, receiver or trustee shall forfeit to the United States the sum of five hundred dollars for each such offense and for each and every day of the continu-

ance of such offense, such forfeitures to be recoverable in the same manner as other forfeitures provided for in section sixteen of the Act to regulate commerce.

"That the district courts of the United States shall have jurisdiction, upon the application of the Attorney-General of the United States at the request of the Commission, alleging a failure to comply with or a violation of any of the provisions of this section by any common carrier, to issue a writ or writs of mandamus commanding such common carrier to comply with the provisions of this section."

Approved March 1, 1913.

ABSTRACT FROM THE RULES AND REGULATIONS OF THE BOARD OF RAILWAY COMMISSIONERS FOR CANADA.

MAPS AND PROFILES.

REQUIREMENTS ON APPLICATION HAVING REFERENCE TO PLANS.

No. 1.—General Location of Railway.—Section 157.

Send to Secretary of the Department of Railways and Canals: 3 copies of *map* showing the general location of the proposed line of railway, the termini and the principal towns and places through which the railway is to pass, giving the names thereof, the railways, navigable streams and tidewater, if any, to be crossed by the railway, and such as may be within a radius of thirty miles of the proposed railway, and generally the physical features of the country through which the railway is to be constructed.

First copy to be examined and approved by the Minister and filed in the Department of Railways and Canals.

Second copy to be approved by Minister for filing by the Minister with the Board.

Third copy to be approved by Minister for the company. Scale of map—not less than 6 miles to the inch.

No. 2.—Plan, Profile, Etc., of Located Line.—Section 159.

Upon approved general location map being filed by the Minister with the Board, send to the Secretary of the Board three sets of plans, prepared exactly in accordance with the "general notes," as follows:

First set—	1 plan. 1 profile. 1 book of reference.	For sanction and deposit with the Board.
Second set—Same as first.		To be certified as copy of original and returned to the Company for registration.
Third set—Same as first.		To be certified as copy of original and returned to the company.

Scale—Plans—400 feet to the inch.

Profiles. { Horizontal, 400 feet.
Vertical, 20 feet.

(N. B.—In prairie country, scale of plan may be 1,000 feet to the inch.)

No. 3.—To Alter Location or Grades of Line Previously Sanctioned or Completed.—Section 167.

Send to the Secretary of the Board three sets of plans, profiles and books of reference as required in No. 2.

(N. B.—The plans and profiles so submitted will be required to show the original location, grades and curves as far as possible, and railway, highway and farm crossings, and the changes desired or necessitated in any of these, giving reason for same. Upon completion of the work application must be made to the Board for leave to operate.

(Scale—Same as No. 2.)

No. 4.—Plans of Completed Railway.—Section 164.

Send to the Secretary of the Board within six months after completion three sets of plans and profiles of the completed road.

First set to be filed with the Board.

Second set to be certified as copy of plan filed, and returned to the company.

Third set to be certified as copy of plan filed. To be returned to the company for registration purposes.

Scale—Same as No. 2.

No. 5.—To Take Additional Lands for Stations, Snow Protection, Etc.—Section 178.

Send to the Secretary of the Board three set of plans and documents as follows:

First set—	1 application sworn to by officers required to sign and certify plans. See "General Notes." 1 plan, 1 profile. 1 book of reference.	To be examined and certified and deposited with Board.
Second set—Same as first.	For certificate and return for registration with duplicate authority.	
Third set—Same as first.	For certificate and return to company, with copy of authority.	

Scale—Same as No. 2.

N. B.—Ten days' notice of application must be given by the applicant company to the owner or possessor of the property, and copies of such notice with affidavits of service thereof must be furnished to the Baord on the application.

No. 6.—Branch Lines, Not Exceeding Six Miles.—Sections 221-225.

Plans, etc., shall be prepared the same as in No. 2; and one set shall be deposited in the Registry Office. Upon such deposit the company shall give four weeks' public notice of its intention to apply to the Board, in some newspaper published in the county or district through which the branch line is to pass; or, if there should be no newspaper published in such county or district, for the same period in the Canada Gazette.

Then send to the Secretary of the Board an application, accompanied by proof of public notice, and three copies of the plan, profile and book of reference, one set bearing the certificate of the Registrar that it is a true copy of the plan, profile and book of reference deposited in the Registry Office.

After the Board has approved the plan, etc., a certified copy of the Order authorizing the construction of the branch line shall be filed in the Registry office, together with any papers and plans showing changes directed by the Board.

No. 7.—Railway Crossings or Junctions.—Section 227.

Send to the Secretary of the Board with an application three sets of plan and profile of both roads on either side of the proposed crossing for a distance of one mile in each direction.

Scale—Plan—400 feet to the inch.

Profile. { 400 feet to inch horizontal.
20 feet to inch vertical.

First set for approval by and filing with the Board.

Second and third sets to be certified and furnished to the respective companies concerned, with certified copy of order.

No. 8.—Highway Crossings.—Section 235 to 243.

Standard regulations of the Board affecting highway crossings, as amended May 4, 1910.

Unless otherwise ordered by the Board, the Regulations regarding the future construction of highway crossings are and shall be as follows:

1. With each application, the railway company shall send to the Secretary of the Board three sets of plans and profiles of the crossing or crossings in petition:

Scale—

Plan ....400 ft. to an inch.

Profile of railway..{ Horizontal ....400 ft. to an inch.
Vertical .... 20 ft. to an inch.

Profile of highway. { Horizontal ....100 ft. to an inch.
Vertical .... 20 ft. to an inch.

First set for approval by and filing with the Board.

Second and third sets, to be furnished to the respective parties concerned, with a certified copy of the order approving of the same.

2. The plan and profile shall show at least one-half mile of the railway each way and 300 feet of the highway on each side of the crossing.

3. The plan shall show all obstructions to the view from any point on the highway within 100 feet of the crossing to any point on the railway within one-half mile of the said crossing.

4. The company shall give the municipality in which the proposed crossing lies, 10 days' notice of the application, and copies of the plan, and furnish the Board with proof of service.

5. The road surface of level or elevated approaches, and of cuts made for approaches, to rural railway crossings over highways shall be 20 feet wide.

No. 10.—Crossings With Wires or Other Electrical Conductors.—Section 246.

Notice to Applicants: Send to the Secretary of the Board with the application three copies of a drawing containing *plans* and *profile* views of the crossing. Also send proof that the railway company has been served with a copy of the application and drawing.

Make the drawing show:

(a) The location of the poles or towers, or the location of the underground conduit in relation to the track; the dimensions of poles or towers, and the material or materials of which they are made.

(b) The proposed number of wires or cables, the distances between them and the track, and the method of attaching the conductors to the insulators.

(c) The location of all other wires to be crossed and their supports.

(d) The maximum potential, in volts, between wires, the potential between the wires and the ground, and the maximum current, in amperes, to be transmitted.

(e) The kinds and sizes of wires or conductors to be used at the crossing.

(f) On circuits of 10,000 volts or over, the method of protecting the conductors from arcs at the insulators.

(g) The number of insulators supporting the conductors at the crossing. (*See also "J" in Specifications.*)

N. B.—Place a distinguishing name, number, date and signature upon the drawing. Mark the exact location of the proposed crossing upon the drawing, so that this crossing can be identified readily.

No. 11.—Crossings With Pipes for Drains, Water Supply, Gas, Etc. —Section 250.

Send to the Secretary of the Board, with the application, a plan and profile in triplicate. The plan must show the track or tracks proposed to be crossed. The profile must show the distance between the pipe and the base of rail, the size of the pipe, and the material of which it is to be

constructed. A copy of the plan and profile must be sent to the railway company with notice of application.

No. 12.—Crossings and Works Upon Navigable Waters, Beaches, Etc.—Section 233.

Upon site and general plans being submitted to Department of Public Works, and being approved by the Governor in Council, send to the Secretary of the Board: Certified copy of Order in Council with the plans and description approved thereby and so certified—one application and two sets of detail plans, profiles, drawings and specifications.

The plans must show details of construction of piers and their foundations, also details of superstructure, if standard plan of the same has not already been approved.

The profile must show the cross-section of the river or stream at the place of crossing and high and low water marks.

The name of the river or stream and the mileage of the bridge should be given.

Upon completion of work application must be made to the Board for leave to operate.

No. 13.—Bridges, Tunnels, Viaducts, Trestles, Etc., Over 18 Ft. Span.—Section 257.

(*a*) Must be built in accordance with standard specifications and plans, approved of by the Board.

(*b*) Or detail plans, profiles, drawings and specifications, which may be blue, white or photographic prints, must be sent to the Secretary of the Board for approval, etc., as in No. 12.

No. 14.—Station Grounds and Station Buildings.—Section 258.

Send to the Secretary of the Board three sets of plans showing the location and details of structures and yard tracks. The company shall give the municipality in which the proposed station lies notice of the application and copy of the plan, and furnish the Board with proof of service.

First set for filing with the Board.

Second set to be certified and returned to the company with certified copy of order of approval.

Third set to be certified and sent to the municipality.

GENERAL NOTES.

Plans (for Nos. 2 to 6) must show the right of way, with lengths of sections in miles, the names of the terminal points, the station grounds, the property lines, owners' names, the areas and length and width of land proposed to be taken, in figures (every change of width being given), the curves and the bearings, also all open drains, watercourses, highways, farm roads and railways proposed to be crossed or affected.

Should the company at any place require right of way more than 100 feet in breadth for the accommodation of slopes and side ditches, it will be necessary to place on the plan cross-sections of the right of way, taken one hundred feet apart and extending to the limits of the right of way proposed to be taken.

Profiles shall show the grades, curves, highway and railway crossings, open drains and watercourses, and may be endorsed on the plan itself.

Books of reference shall describe the portion of land proposed to be taken in each lot to be traversed, giving numbers of the lots, and the area, length and width of the portion thereof proposed to be taken and names of owners and occupiers so far as as they can be ascertained.

All plans, profiles and books of reference must be dated and must be certified and signed by the President or Vice-President or General Manager, and also by the Engineer of the company.

The plan and profile to be ertained by the Board must be on tracing *linen,* the copies to be returned may be either white, blue, or photographic prints.

All profiles shall be based, where possible, upon sea level datum.

All books of reference must be made on good, thick paper and in the form of a book with a suitable paper cover. The size of such books when closed shall be as near as possible to 7½ inches by 7 inches, or book of reference may be endorsed on the plan.

REPORT OF COMMITTEE II—ON BALLAST.

H. E. Hale, *Chairman;*
L. W. Baldwin,
D. P. Beach,
W. J. Bergen,
A. F. Blaess,
T. C. Burpee,
O. H. Crittenden,
F. T. Darrow,
J. M. Egan,
T. W. Fatherson,
H. L. Gordon,

J. M. Meade, *Vice-Chairman;*
G. H. Harris,
C. C. Hill,
S. A. Jordan,
William McNab,
A. S. More,
J. V. Neubert,
S. B. Rice,
E. V. Smith,
F. J. Stimson,
S. N. Williams,

Committee.

To the Members of the American Railway Engineering Association:

Your Committee respectfully submits herewith its report to the fifteenth annual convention.

The following subjects were assigned your Committee for investigation, by the Board of Direction:

(1) Further investigation of proper depth of ballast of various kinds to insure uniform distribution of loads on roadway, conferring with Committee on Roadway.

(2) Revise ballast sections, with particular reference to the use of a sub- and top-ballast.

(3) Investigate methods of cleaning stone ballast and obtain cost of same by various methods.

(1) BALLAST SECTIONS, WITH PARTICULAR REFERENCE TO THE USE OF SUB- AND TOP-BALLAST.

Meetings of the Sub-Committee were held at St. Louis, July 18, and Chicago, November 13, 1913.

The members of the Sub-Committee are: J. M. Meade, Chairman; F. T. Darrow, S. N. Williams, A. F. Blaess, C. C. Hill, D. P. Beach, A. S. More.

Your Committee considered plans of ballast sections of various railroads and results of tests reported to the Association by the Committee on Ballast.

For the purpose of ready reference and to place this subject clearly before the Association, there appears in Appendix A the ballast sections of some of the principal railroads of Canada, United States and Mexico.

In Appendix B will be found a composite drawing showing the ballast sections of some of the principal roads of the United States, and on this drawing is shown the proposed ballast section recommended by the Committee on Ballast. This composite drawing gives a very good idea of

the general trend of ballast sections and indicates how the proposed ballast section will conform with present practice.

There was much discussion in the Committee meeting in regard to the various dimensions of the proposed ballast sections, and your Committee finally came to fairly definite conclusions by passing on one point at a time, as follows:

(a) In Class A stone ballast section, the top-ballast shall consist of broken stone, and, where economical, there shall be a sub-ballast of fine material, such as cinders, gravel, or granulated slag.

(b) The depth of ballast shall be 24 in., and on curves the depth of 24 in. shall be maintained under the low rail.

(c) Where top- and sub-ballast is used, the thickness of the top or coarser ballast shall be 12 in. and the thickness of the sub-ballast, or finer material, shall be 12 in.

(d) The slope of the ballast on the side shall be 2 to 1, and the upper corner shall be rounded off with a 4-ft. radius.

(e) The top of the ballast shall slope with a grade of ½-in. to 1 ft., from a point in the center of the track at the top of the tie to the intersection with the 4-ft. radius above-mentioned, to avoid interference with track circuit.

(f) In a general way the proposed plan of the Baltimore & Ohio Railroad should be followed.

(g) The top of the sub-grade shall not be level, but shall be raised in the center to provide drainage.

Appendix C—proposed Class A ballast section—is in a general way the same as the proposed ballast sections of the Baltimore & Ohio Railroad.

On the following page are shown two photographs of the standard ballast section of the Eastern Division of the Pennsylvania Lines West, with 24 in. of ballast under the tie.

Your Committee endeavored to have several sections of track put up on 24 in. of ballast, in accordance with the ballast section which they recommend, but without success, and they feel that this subject cannot be thoroughly studied and definite conclusions drawn unless the proposed ballast section is actually put in service and attention given to the process of installing the ballast, as well as maintaining the track on the proposed ballast section.

CONCLUSIONS.

Your Committee offers to the Association for favorable consideration the proposed ballast section shown in Appendix C with 24 in. of ballast under the tie, using a top-ballast of broken stone and a sub-ballast of finer material, such as gravel. Your Committee wishes to call particular attention to the fact that the sub-grade is wider from the center line to the outer edge on the outside of curves than it is on the inside, which appears to be the most economical method of providing for the slope of 24 in. of ballast.

STANDARD BALLAST SECTION, PENNSYLVANIA LINES, EASTERN DIVISION.

Your Committee recommends that these ballast sections be put in service for short stretches on some railroad during the early part of 1914 and full report of process of applying and results of maintenance of same be made to the Association with final conclusions, if possible, in the 1915 report.

(2) METHODS OF CLEANING STONE BALLAST AND COST OF SAME BY VARIOUS METHODS.

The following is the personnel of the Sub-Committee: S. A. Jordan, Chairman; H. L. Gordon, S. B. Rice, J. V. Neubert, E. V. Smith, J. M. Egan, T. W. Fatherson.

The Sub-Committee has held no meetings except the regular meetings in St. Louis, July 18, and Chicago, November 13, 1913, as it was believed that the necessary information could be obtained by letter as well as by meeting.

The following suggestions were made by the Chairman, Mr. H. E. Hale, in connection with the investigation of the subject:

(a) Ascertain what methods are being used for cleaning stone ballast and cost of same.

(b) Refer to test of Baltimore & Ohio, printed in last year's report.

(c) Obtain copies of any articles printed in engineering magazines or reports on this subject which will be of interest to the Association.

(d) Obtain any other data on this subject which will be of interest.

The Pennsylvania Railroad have made tests on two divisions the past year, under the following instructions:

PROPOSED TEST TO DETERMINE THE AMOUNT OF BALLAST LOST IN CLEANING ONE MILE OF DOUBLE TRACK.

"Select two stretches of double track one-half mile in length, one on the Pittsburgh and one on the Eastern Division, which are ballasted with stone to the full section, but in which the ballast is choked with cinders or mud, and which requires cleaning.

"Clean the ballast in these stretches of track in the usual manner by shaking the ballast on forks, throwing the clean ballast retained on the forks back into the track and the small particles of ballast and dirt which pass between the tines of the forks into piles, being careful to see that none of it is lost. While this is being done, be careful to see that the track is not raised during the cleaning operation. The space between the ties should be cleaned to the base of the ties and the shoulders outside of the ties, and the space between tracks to 12 in. below the base of the ties.

"After this work shall have been completed, fill in the track to the full section, making note of the number of cubic yards of new ballast required. From the length of track cleaned and the number of cubic yards of new ballast required to fill in the track to full section after cleaning the old ballast, calculate the number of cubic yards lost per mile of double track by cleaning.

"Then pass the dirt which passes between the tines of the forks over a screen having a ¾-in. mesh and measure the number of cubic yards of small particles of stone reclaimed. From this calculate the number of

cubic yards of ballast lost per mile as a result of the existing imperfect method of cleaning."

Letter reports were made, showing the results of these tests:

"We have had a test made to determine the amount of ballast lost in cleaning one mile of double track. This test was made on one-half mile of double track located between milepost 144-3300 and milepost 145-660, near Shreve, Ohio, Eastern Division.

"This work was done in the usual manner, with ballast forks, and the dirt was thrown onto piles. The space between the ties was cleaned to the bottom of the ties, and the shoulders outside the track and the space between the tracks to a depth of 12 in. below the base of the ties. The dirt was screened over a ¾-in. mesh screen. The stone reclaimed by cleaning was 10 cu. yds.

"The track was then filled to its full ballast section with new ballast. This required 285 cu. yds. of new ballast.

"The cost of labor for cleaning this one-half mile of double track was $537.30.

"The cost of screening 10 cu. yds. of stone out of the dirt was $159.10. No lift was made in the tracks.

"From the above, we calculate the cost of cleaning the ballast on one mile of double track to be $1,074.60, the cost of screening the stone out of the dirt to be $318.20, and the number of cubic yards lost screening to be 570. . . . .

"We have completed the experiment outlined in the instructions by cleaning the stone ballast in one-half mile of double track on stretch beginning at the east end of No. 5 tunnel and extending eastwardly for one-half mile, where the ballast was choked with cinders and mud, with the following results for one-half mile of double track:

New ballast required after cleaning old ballast	163 cu. yds.
Ballast lost per one-half mile of double track by cleaning	75 cu. yds.

"From the figures shown above we calculate that there would be 326 cu. yds. of ballast lost per mile of double track by ordinary cleaning and that by using a ¾-in. mesh screen 150 cu. yds. per mile could be saved. However, this seems to be a very expensive way of cleaning ballast.

"It might be of interest to know what this work cost, which is as follows:

Cleaning ballast out of track and forking it back into track	$1,062.00
Screening ballast	105.00
Leveling ballast	64.00
Loading the screenings which did not pass through ¾-in. mesh	28.00
Unloading screenings	32.00
Unloading stone ballast to fill in	11.00
Total	$1,302.00

"From this it will be noted that to reclaim 75 cu. yds. of stone on one-half mile of double track we expended $165.

"It would not have been necessary to have expended the $28 to load the screenings and the $32 to unload them, had we not been required to take accurate measurements to determine the amount of ballast saved by screening, therefore the cost of screening ballast was $105 to reclaim 75 cu. yds."

In addition to this test the following information was obtained in response to circular letter sent to railroads using stone ballast:

W. J. Backes, Engineer Maintenance of Way, New York, New Haven & Hartford Railroad:

"Relative to cleaning ballast, we have cleaned some ballast on our New York and Shore Line Division. The work is done as follows:

"When renewing ties, a shovel is used to remove the ballast from track, in preparation to taking out the old ties. After the new ties are installed, stone is forked back into the track, the dirt being left in the middle gages. The dirt is then picked up by work train in the cuts and generally on the fills, and is cast or carried out in boxes and used for widening out embankments.

"We have no ballast cleaning organization, nor have we made any comparative tests of various methods.

"We find that it costs about $2,500 per mile of four tracks to do this work where the tracks have not been previously cleaned by sectionmen, and the dirt left in the middle gages."

Jos. O. Osgood, Chief Engineer, Central Railroad Company of New Jersey:

"The only method of cleaning ballast has been the ordinary one—by the use of ballast forks.

"We have no fixed organization for this purpose. The ballast in the track is cleaned by our section or extra-gang forces, as the necessity for it occurs.

"We have not conducted any tests of the different methods. Mr. Stein, Engineer Maintenance of Way of the Central Division, informs me that he has found that it costs from 7½ cents to 12 cents per linear foot on a double-track road to clean the ballast down to the bottom of the tie, including the shoulder on the ditch side and up to the middle point in the center ditch, digging the center ditch down to actual sub-grade in order to divert all of the water from between the ties either to the side ditch or to the center ditch. In four-track districts this cost is from 12½ cents on the outside tracks to 17 cents per linear foot on the inside tracks.

"We have made no special investigation to determine the amount of ballast lost by cleaning, but from such information as we have, it is estimated that we lose from five to ten carloads; or from 150 to 300 yds. of ballast per mile of track, when cleaned at intervals of three years."

Geo. W. Kittredge, Chief Engineer, New York Central & Hudson River Railroad:

"We clean ballast. This is done by laborers with ballast forks. We have no regular organization for cleaning ballast, but the regular track maintenance gangs do it in connection with their work of putting in ties, surfacing and lining over the track, except where substantial changes or raising of track is done, which makes it advisable to clean out the ballast first and then deposit new ballast on top. Occasionally, where the grade of the track is substantially changed, the ballast is forked out before the lift is made, so as not to affect the drainage, but under ordinary conditions, each section gang forks out the ballast on a portion of the section needing it most each year.

"We have made no tests of other methods.

"The amount of ballast lost by cleaning cannot be accurately measured, as we cannot separate, in any feasible way, the dust from the ballast

and the dust, cinders, dirt, etc., blown or washed in the ballast. Where we have felt it necessary to fork the ballast, the material removed, consisting largely of dirt, has averaged about 30 per cent. This is the result of measuring it in several places.

"At one point between tracks we forked 4.6 cu. ft. of ballast, which yielded about 1.4 cu. ft. of dirt, divided as follows:

16 per cent. stone; could not pass through a 1-in. mesh.
24 per cent. stone; passed through 1-in. mesh, but not through ¼-in. mesh.
60 per cent. dirt; passed through ¼-in. mesh.

"Cleaning ballast under and between ties to a depth of 6 in. has averaged on one job we watched .093 cent per linear foot of track. Cleaning ballast in the space between ties, where tracks are 12-ft. centers, has averaged .154 cent per linear foot of track.

"These figures are, of course, for four-track sections under average traffic on this division, which is rather heavy, and I assume the cost would be reduced very much where there are fewer tracks, so that the cost of removing material screened from the ballast would not be so large.

"We have to carry by hand, usually, at least, over one-third rail and sometimes more than that, to get it to a place where it can be disposed of, or picked up by the work train.

"We had one case in the Park Avenue Tunnel, New York City, where the cost of forking out ballast made it cheaper to load it, take it away and use it on sidetracks and bring the new ballast down and dump it. This was an unusual condition where wet mud made it particularly hard to fork the ballast and limited clearance made it expensive for men to work."

F. S. Stevens, Engineer Maintenance of Way, Philadelphia & Reading Railway:

"Our practice is to clean ballast when we renew ties by digging out the old ballast between ties nearly to sub-grade and take about 2 in. from the bed of the tie that has been removed, thereby getting nearly all of the dirt. When the new tie has been placed, the ballast is replaced with a fork, care being taken to screen out in this way all dirt and fine stone that will fall between a ballast fork having ten tines.

"We do not have any other cleaning organization. We have made no comparative test of various methods. We have made no tests to show the percentage of ballast lost by cleaning."

Appendix B of last year's report on the subject of "Cleaning Stone Ballast by Use of Screens," by W. I. Trench, Division Engineer, Baltimore & Ohio Railroad, is supplemented by Appendix D to this report.

This report contains full description of tests that have been carried on on the Baltimore & Ohio, together with description and plans of screens, explanation of organization and costs of doing the work.

The screens described are covered by patents owned by Mr. Trench and Supervisor A. G. Zepp of Baltimore. The cost of these screens is about $150 for set of three.

The following table shows a comparison of cost of cleaning ballast on several roads and by different methods. It will be seen that the costs vary widely, due to the various methods employed and the various depths to which ballast was cleaned.

However, the efforts to make the test recommended by the Committee on Ballast above-mentioned, failed and to date no method has been arranged for by which this test can be financed.

At a meeting of the Committee on Ballast as a whole, at St. Louis, July 18, a review of this subject developed the fact that little additional information could be hoped for until such time as some actual tests might be made upon track subjected to usual traffic stresses, but the Sub-Committee was instructed by the Chairman of the Committee on Ballast to endeavor to obtain any further information possible which might be of interest to the Association.

The Chairman of this Sub-Committee requested the other members, by letter, to submit whatever information might be found bearing on this subject, and also devoted several days to a search through the files of the various scientific periodicals, but nothing was found to supplement the references given in the Ballast Committee's report for the year 1912 in Vol. 13 of the Proceedings.

On November 13, 1913, at a meeting of the Committee in Chicago, your Committee was unanimous in feeling that the test recommended by it in its annual report of 1913 should be made, in addition to the Roadway Committee's test referred to above; as it in no way conflicts with the Roadway Committee's test and gives information which your Committee believes will not be given by that test. Your Committee has given a great deal of consideration to the subject of the best manner to determine the proper depth of ballast, and have discarded several proposed tests and devices for measuring the distribution of the loads on the sub-grade, and they are convinced that no test so far suggested will cover the point in question so completely as the test recommended by your Committee on Ballast in its annual report of 1913, as this test is proposed to be made under regular traffic.

Your Committee therefore requested President Wendt to ask five roads each to make the test at their own expense, on the basis that the expense of the test would be more than offset by the information gained to determine the economical depth of ballast.

This proposition was placed before the Board of Direction on November 20 and President Wendt advised as follows:

"The Board is strongly of the opinion that the present financial situation will cause many roads to decline to invest any money in experiments at this particular time, and this explains the proviso that the Secretary and President are cautioned to present the request to the railroads at whatever seems to be the most opportune time. In other words, the Board has approved the proposition and the Executive Officers will give this matter proper attention. . . . . Permit me to say that the Board of Direction was unanimous in its approval of the proposition, and only regrets that the time is not opportune for approaching the roads at once."

For ready reference, the following is a copy of test recommended in 1913, and an estimate of cost. This estimate is probably high, and was intentionally made so. It is believed that by careful handling the test can be made for much less money than the following estimate, as any railroad

which is purchasing stone ballast could easily afford to disregard the item of $400 for stone ballast:

"(1) Select a stretch of track on clay roadbed, under heavy traffic, where trouble has been experienced with clay working up between the ties.

"(2) Excavate roadbed to a uniform depth of 30 in. below the bottom of the ties, for a space of two rail-lengths; prepare the adjacent rail-lengths in the same manner, decreasing the depth 3 in. under each successive two rails, until the bed is 12 in. below the bottom of the tie (14 rail-lengths).

"(3) Place on this bed a thin layer of fibrous material, such as hay, to make a well-defined separation between roadbed and ballast.

"(4) Place stone ballast on bed to the above-mentioned depths, tamp well, and put track in good line and surface.

"(5) Make note of tie-spacing, width of ties, keep accurate levels, and record of amount of time spent on surfacing various parts of track, also keep record of axleloads and amount of traffic. Take photographs at regular intervals to show deformation of roadbed.

"(6) Make similar test for gravel and similar for ballast section, having a sub-ballast of gravel equal to one-half the total depth and a top ballast of stone equal to one-half the total depth of ballast.

"(7) The estimated cost of this test is as follows:

(a)	Cost of material (stone), 500 yds. at 80 cents..............	$ 400.00
(b)	Labor, preparing track and widening bank, where necessary, at $30.00 per rail (14 rails per test)..................	420.00
(c)	Labor, inspecting, six inspections at $2.00 per rail..........	170.00
(d)	Line and surface to be paid for by railway owning track, at regular maintenance charge.......................	......
	Total for one test..................................	$ 990.00
	Three tests	$3,000.00

In view of the dearth of authoritative information on this subject and the fact that all experiments to date have been made under artificial conditions, your Committee feels if further reliable information is to be procured that a further test must be made.

RECOMMENDATIONS.

Your Committee again unanimously recommends that the test outlined in its 1913 report, as above printed, be made under regular traffic.

Your Committee recommends that several railroads be asked to make the test at their own expense, as approved by the Board of Direction, and that the test be made under the direction of the Committee on Ballast, preferably on a road on which a member of the Committee on Ballast is located.

Your Committee feels that the gain to any large railroad system resulting from the knowledge of the proper depth of ballast is so great and the cost of the test so small by comparison, that the test should be made in the immediate future.

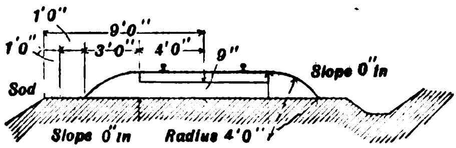
Respectfully submitted,

COMMITTEE ON BALLAST.

Appendix A.

BALLAST SECTIONS OF VARIOUS RAILROADS.

CRUSHED STONE OR SLAG.



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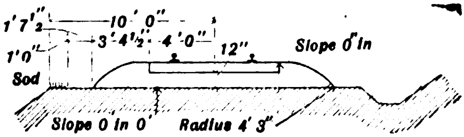
Baltimore & Ohio Railroad.



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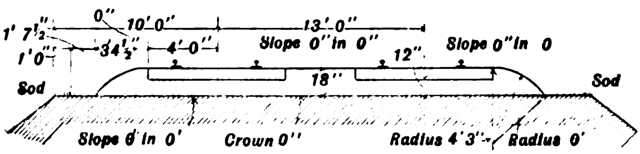

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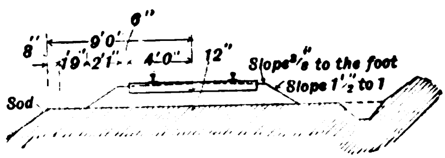


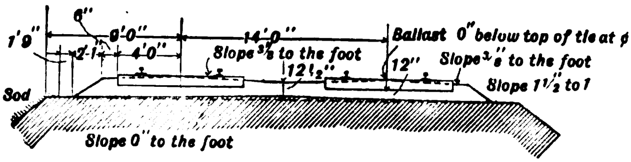
Tie, 6 in. by 8 in. by 8 ft. 0 in.

Chicago, Burlington & Quincy Railroad,

APPENDIX B.

COMPOSITE DRAWING OF VARIOUS BALLAST SECTIONS.

CRUSHED STONE OR SLAG.



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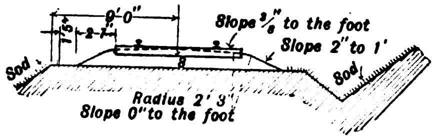
Chicago, Burlington & Quincy Railroad.



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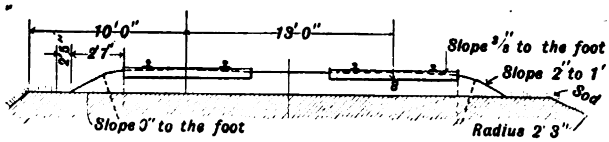
Chicago, Rock Island & Pacific Railway.



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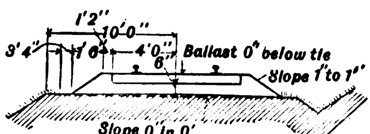
Chicago, Rock Island & Pacific Railway.



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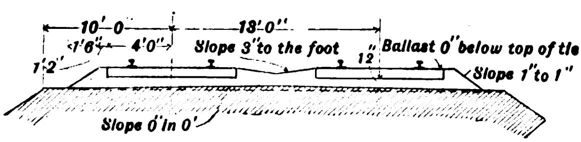
Chicago & Northwestern Railway.



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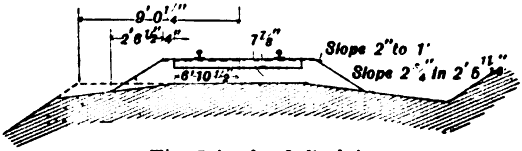
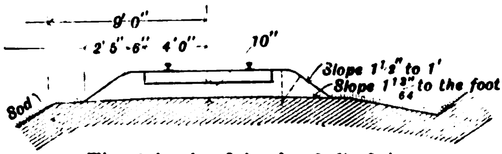
Chicago & Northwestern Railway.

CRUSHED STONE OR SLAG.



Tie, 7 in. by 8 ft. 0 in.

Ferrocarriles Nacionales de Mexico.



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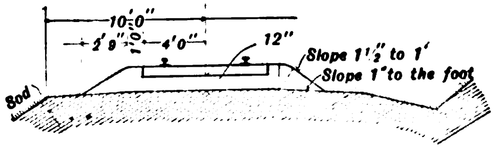
Illinois Central Railroad.



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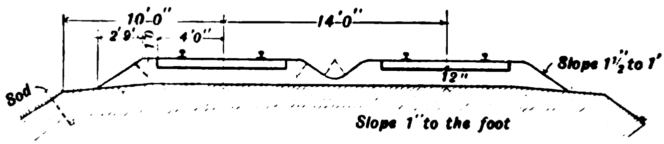
Illinois Central Railroad.



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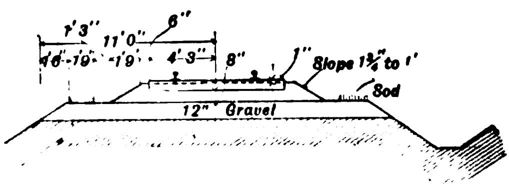
Illinois Central Railroad.



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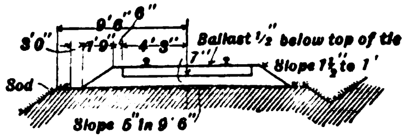
Lake Shore & Michigan Southern Railway.

CRUSHED STONE OR SLAG.



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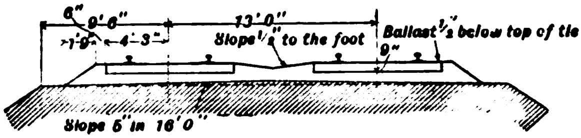
Lehigh Valley Railroad.



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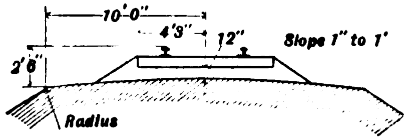
Lehigh Valley Railroad.



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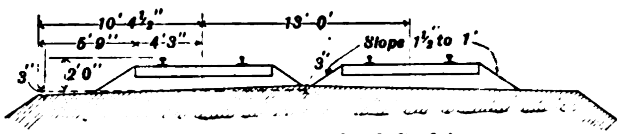
Louisville & Nashville Railroad.



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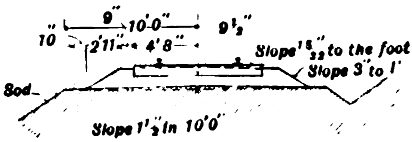
Louisville & Nashville Railroad.



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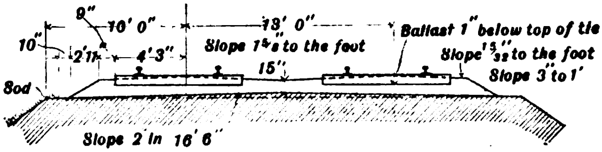
New York Central & Hudson River Railroad.

CRUSHED STONE OR SLAG.



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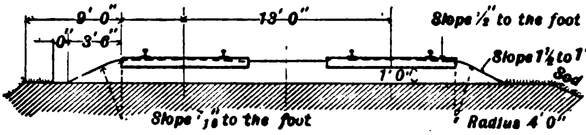
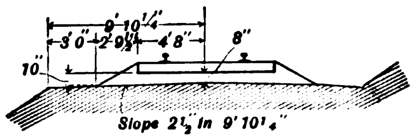
New York Central & Hudson River Railroad.



New York, New Haven & Hartford Railroad.



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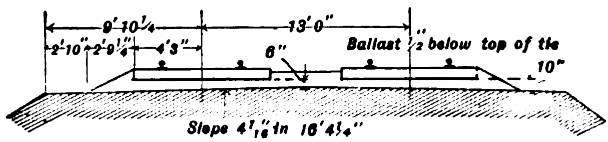
Pennsylvania Lines East.



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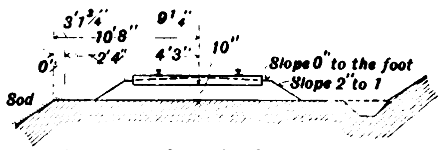

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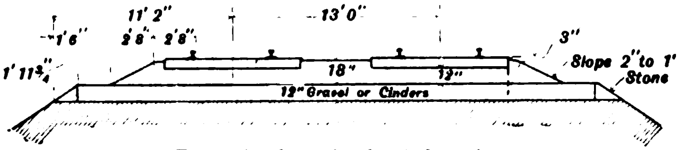
Pennsylvania Lines West.

CRUSHED STONE OR SLAG.



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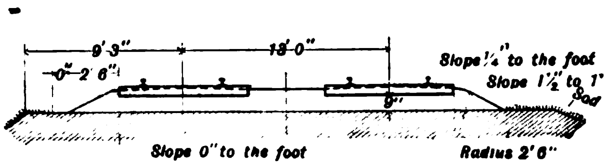
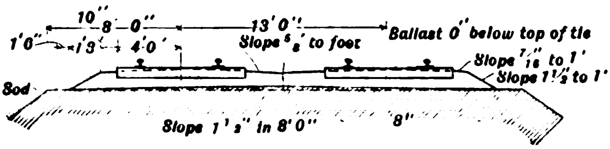


Philadelphia & Reading Railway.



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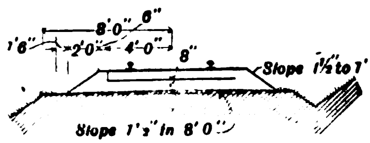
Southern Pacific Company.



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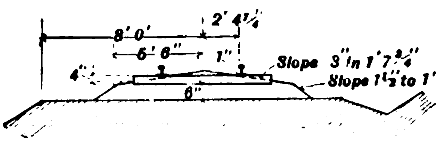
Union Pacific Railroad.

GRAVEL.



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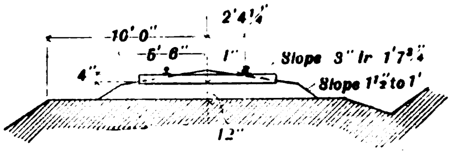
Chicago & Northwestern Railway.

GRAVEL.



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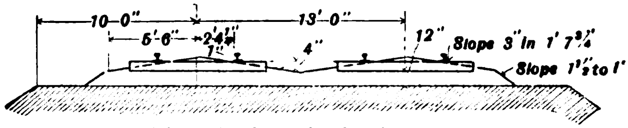

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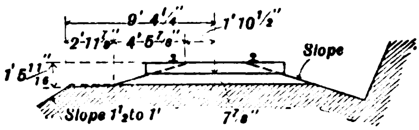
Chicago & Northwestern Railway.



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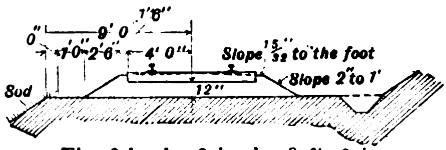
Ferrocarriles Nacionales de Mexico.



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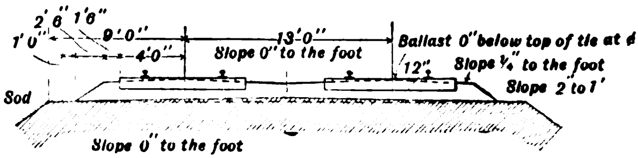
Grand Trunk Railway.



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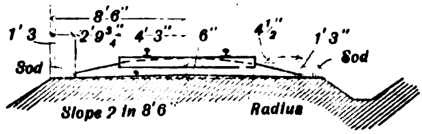
Grand Trunk Railway.

GRAVEL.



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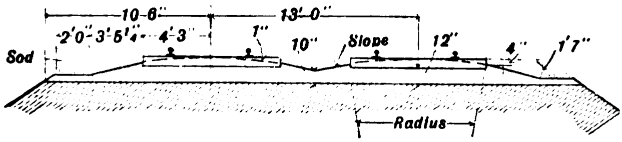
Lake Shore & Michigan Southern Railway.



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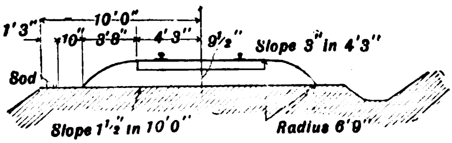
Lake Shore & Michigan Southern Railway.



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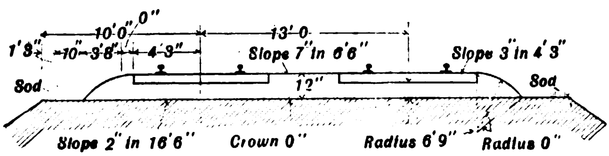
New York Central & Hudson River Railroad.



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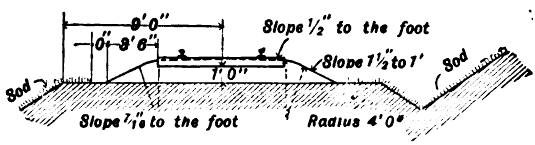
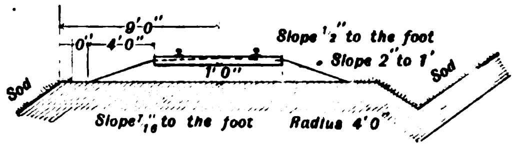
New York Central & Hudson River Railroad.

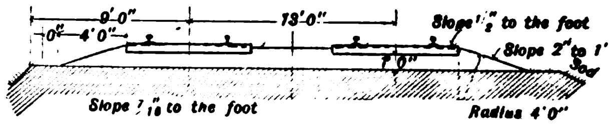


New York, New Haven & Hartford Railroad.

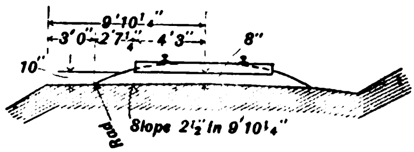
GRAVEL.



New York, New Haven & Hartford Railroad.



New York, New Haven & Hartford Railroad.



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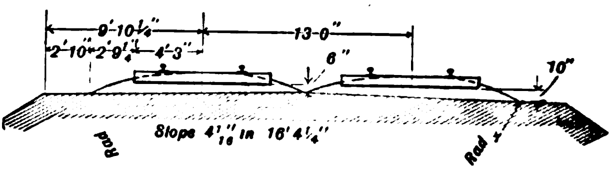
Pennsylvania Lines East.



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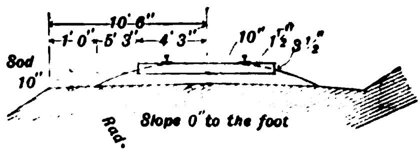

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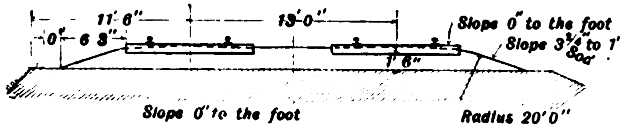
Pennsylvania Lines West.

GRAVEL.



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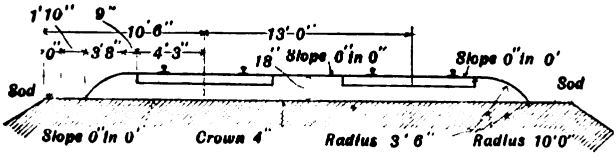

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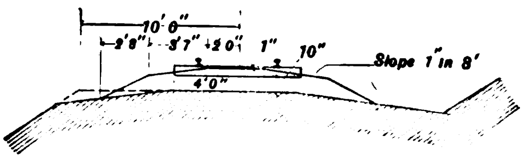
Richmond, Fredericksburg & Potomac Railroad.

CEMENTING GRAVEL.



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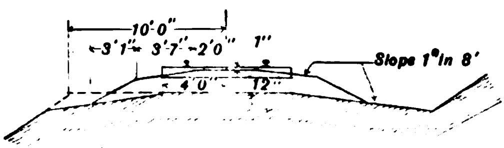
Atchison, Topeka & Santa Fe Railway.



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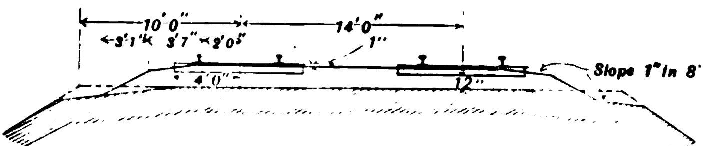

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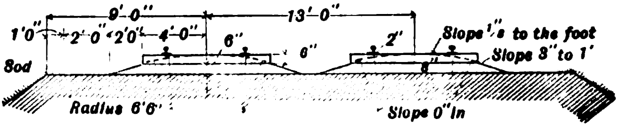
Atchison, Topeka & Santa Fe Railway.

CEMENTING GRAVEL.



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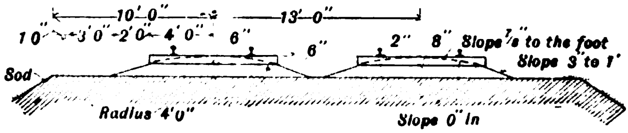
Chicago, Rock Island & Pacific Railway.



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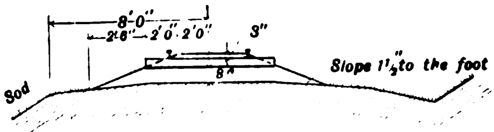
Chicago, Rock Island & Pacific Railway.



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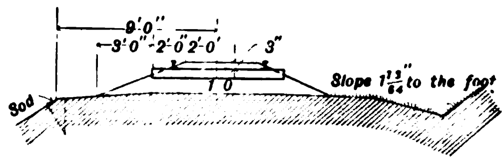
Illinois Central Railroad.



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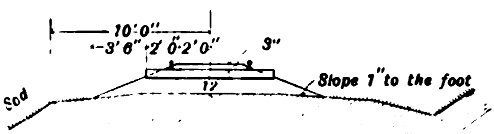
Illinois Central Railroad.



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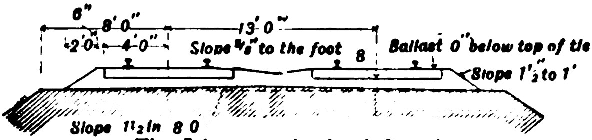
Illinois Central Railroad.

SHERMAN GRAVEL, CRUSHED STONE OR SLAG.



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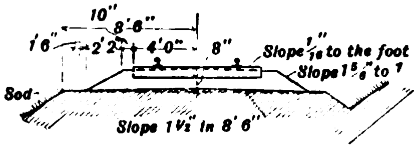
Southern Pacific Company.



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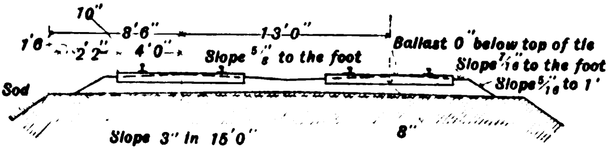
Union Pacific Railroad.



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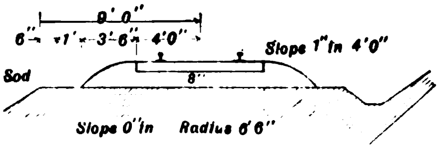
Union Pacific Railroad.

CHATS AND SAND.



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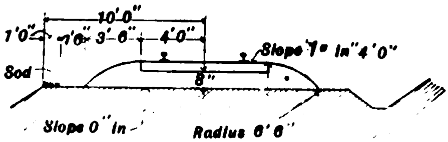
Chicago, Rock Island & Pacific Railway.



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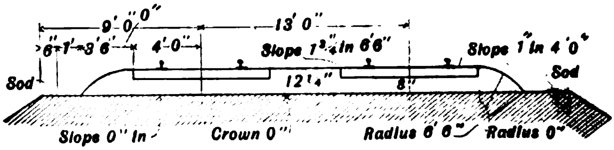
Chicago, Rock Island & Pacific Railway.

CHATS AND SAND.



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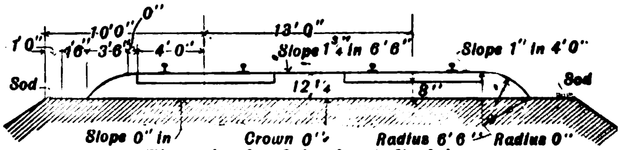
Chicago, Rock Island & Pacific Railway.



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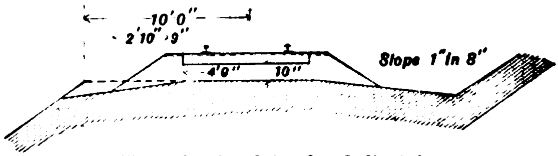
Chicago, Rock Island & Pacific Railway.

BURNT CLAY, GRAVEL OR CINDERS.



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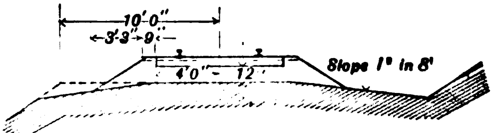
Atchison, Topeka & Santa Fe Railway.



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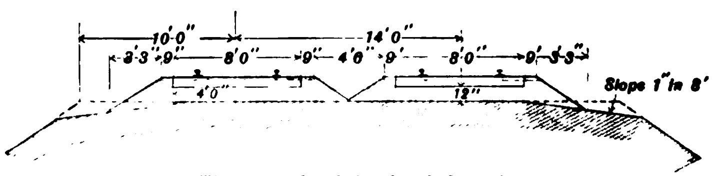
Atchison, Topeka & Santa Fe Railway.



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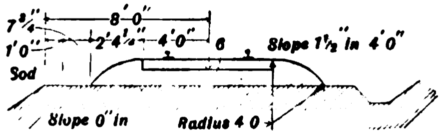
Atchison, Topeka & Santa Fe Railway.

STONE, GRAVEL, CINDERS OR BURNT CLAY.



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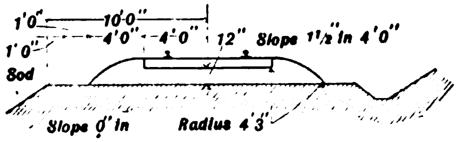
Baltimore & Ohio Railroad.



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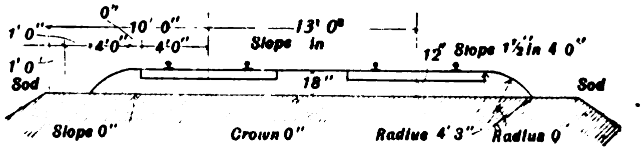
Baltimore & Ohio Railroad.



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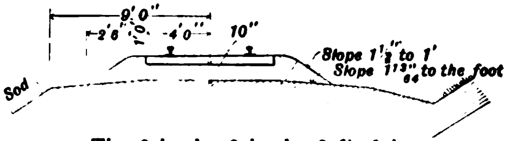
Baltimore & Ohio Railroad.



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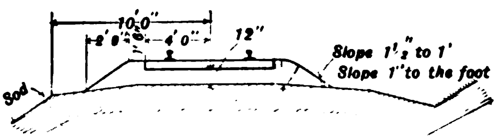
Illinois Central Railroad.



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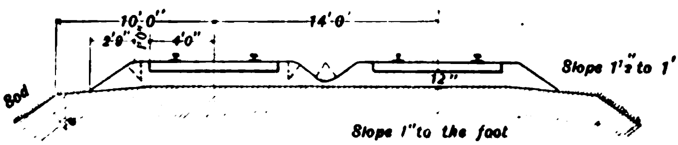
Illinois Central Railroad.



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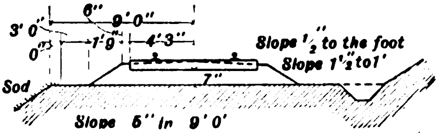
Illinois Central Railroad.

STONE, GRAVEL, CINDERS OR BURNT CLAY.



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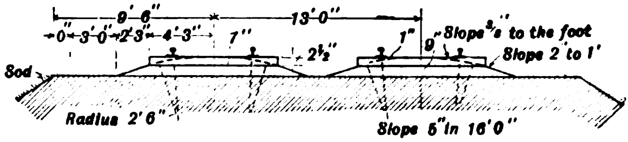
Lehigh Valley Railroad.



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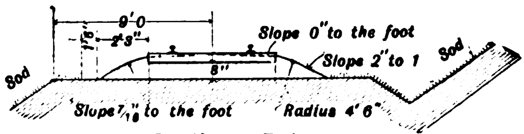
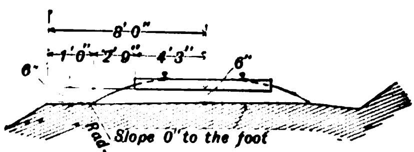
Lehigh Valley Railroad.



Southern Railway.



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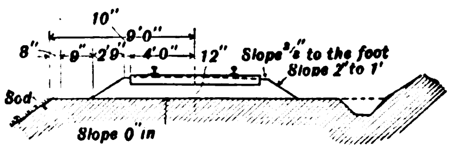
Pennsylvania Lines West.



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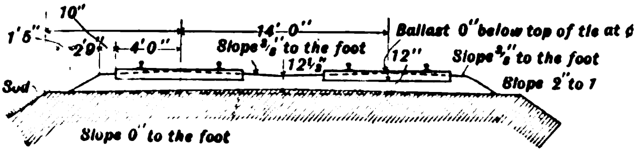
Chicago, Burlington & Quincy Railroad.

GRAVEL, CINDERS OR CHATS.



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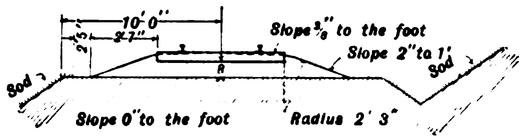
Chicago, Burlington & Quincy Railroad.



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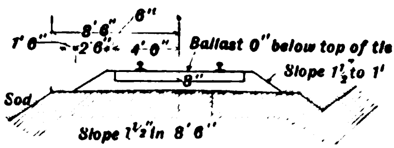
Chicago, Rock Island & Pacific Railway.



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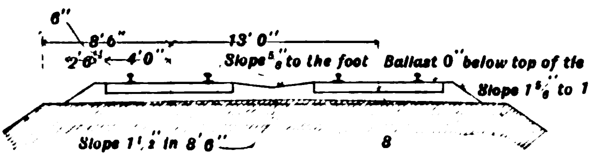
Southern Pacific Company.



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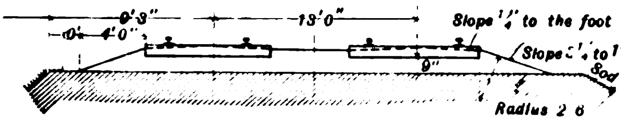
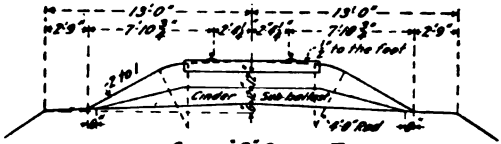


Tie, 7 in. by 9 in. by 8 ft. 0 in.

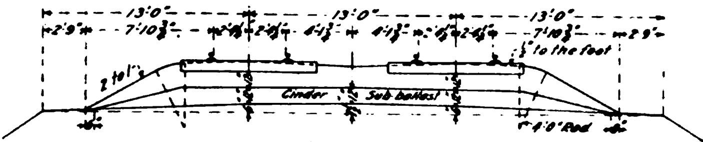
New York, New Haven & Hartford Railroad.

Appendix C.

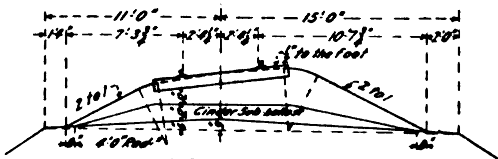
PROPOSED BALLAST SECTIONS.



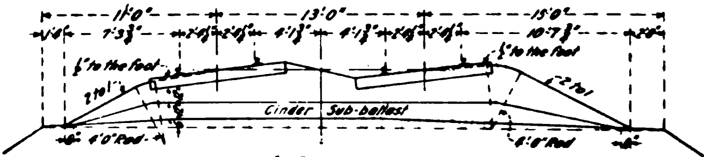
CLASS "A" SINGLE TRACK



CLASS "A" DOUBLE TRACK



CLASS "A" SINGLE TRACK ON CURVE



CLASS "A" DOUBLE TRACK ON CURVE

Appendix D.

CLEANING STONE BALLAST BY MEANS OF SCREENS.

By W. I. Trench, Division Engineer, Baltimore & Ohio Railroad.

DOUBLE-TRACK WORK.

There are several most important reasons for keeping stone ballast clean, which probably do not occur to the casual observer, and this discussion will be prefaced by a few words thereon. There is ever apparent a readiness on the part of the track people to cure all the evils due to dirty compact ballast by raising track and putting under from 4 to 10 in. of new ballast. It is true that this gives instant relief, but the relief by the light raise is but temporary, and by the heavier raises extremely wasteful after the required amount has been put under the track to properly distribute the load. Assuming that we have this amount of ballast under the track and that it has been there for several years without raise, we will probably find to exist the following undesirable conditions:

BAD EFFECTS OF DIRTY BALLAST.

(a) Main track line, surface and gage very bad (these conditions are so related that they never occur singly, as one produces the others) or extraordinary force required to maintain good line, surface and gage, due to dirty ballast, which will not drain properly. (The familiar expression, "centerbound," refers to a related condition, where ballast has become old and track so settled in it that there is more bearing in the middle of the tie than under the rail, and surface reverses from side to side as though track were supported by a ridge in the center.)

(b) Rail is observed to be deteriorating rapidly, due to bad line, surface and gage.

(c) Ties are deteriorating rapidly by mechanical wear, and tendency of track to run, due to bad line, surface and gage and bad rail, and decaying faster, due to dirty ballast retaining moisture.

(d) Tractive effort required to move tonnage is increased, due to bad line, surface and gage and bad rail, with consequent increase in cost of operation.

(e) Undesirable impression is given to patrons of the road by rough ride, due to bad line, surface and gage, with its consequent loss of revenue.

(f) Weeds thrive luxuriantly, giving an undesirable impression to patrons of the road for a portion of the year, with consequent loss of revenue, and requiring the annual June and September weed-pulling at a cost of from $50 to $150 per double-track mile per annum.

(g) Road is dusty, giving it bad impression to patrons during a large part of the year, at open windows and on observation end, with its consequent loss of revenue.

USUAL EXPEDIENCY.

On account of the past, almost prohibitive, cost of cleaning ballast, as noted above, track is raised, introducing new ballast and covering up the dirt. With a light raise we get relief temporarily from the acute situation we have noted. Line, surface and gage are good for a time and the weed and dust nuisance abated, but the dirty ballast, still being present, soon brings about a condition as bad as before. While a heavy raise produces more permanent results, we forget that:

(a) Stone ballast costs from 45 to 80 cents per cu. yd., and to raise one mile of double track 10 in., 4,380 cu. yds. are required, at, we will estimate, 60 cents per cu. yd., costing:

Material	$2,628.00
Labor, ballasting	1,300.00
Dressing after berm is raised	300.00
Total	$4,228.00

(b) That a 10-in. raise on a 10-ft. fill requires 2,000 cu. yds. of filling per mile to restore standard embankment at, say, 50 cents per cubic yard, amounting to $1,000, and that raising in cuts fills the ditches, and requires widening the cuts, which is very costly.

(c) Continual heavy raising distorts profile of track, requiring raising bridges, platforms and depots and lengthening culverts and requiring greater tractive effort to move tonnage.

ADVANTAGES OF CLEANING BALLAST.

If ballast is cleaned systematically and often, and track is raised only when necessary to put the proper edge on line, surface and gage, or to re-space ties, and then only in small raises of not more than 1½ in., we find that

(a) Line, surface and gage can be maintained at greatly reduced cost, due to improved drainage and equalized bearing.

(b) Life of ties and rail are prolonged by a large percentage.

(c) Weeds do not grow in clean ballast.

(d) There is no dust in clean ballast.

(e) Satisfaction of patrons will be increased, due to better ride, no dust and better general impression.

(f) Cost of labor and material, applying stone ballast and widening fills and cuts occasioned by raising will be saved.

(g) The dirt cleaned from ballast will, if applied between ballast line and shoulder of fill or bottom of cut, present a neat black appearance and pleasing contrast to the white stone ballast properly dressed; will keep down the weeds in this area and keep pace in raising the embankment with the small raises of track made.

(h) Cost of cleaning is less by any method if done often, as amount of dirt to handle is less, this varying from 100 to 400 wheelbarrow loads per 100 ft. of double track.

CLEANING WITH SCREENS.

In the 1913 Proceedings of this Association the report of the Ballast Committee contains a description of a ballast screen, as developed on the Baltimore & Ohio Railroad, which showed that double-track ballast could be cleaned at a cost of $640 per mile, or 56 per cent. less than by the use of forks, leaving ballast dressed up complete, dirt being deposited in wheelbarrows ready for disposal. At present rates of pay, viz., foreman $2.54 and laborers $1.75 per ten-hour day, this would have been $692.80 per mile. The object of the present discussion is to show that by certain improvements in the screen and in gang organization, 200 ft. per day is a conservative figure, with a gang of foreman and 12 men, costing per mile $622, which includes dressing up complete, stone line laid by hand, shortage of ballast due to cleaning left between rails, where shower from a Rodger ballast car will fill cribs without shoveling. (Note between rails, Fig. 1.)

A SHORT DESCRIPTION OF SCREEN.

The screen under discussion consists of woven ¼-in. rods, making a mesh ¾ by 8 in. This gives a perfect separation of stone and dirt far superior to that given by forks. The rods are carried in a light channel frame, which is reversible, end for end, giving double wear. The main frame of the screen is made of light angle iron. The screen is made for use either outside of track or in center ditch. (Figs. 1 and 2.)

When using outside of track, it sits at right angles thereto, and is supported at the lower end by horizontal legs, which ride upon the ties, and at the upper end by adjustable legs, which regulate the inclination of the screen. When in this position it clears the longest Pullman cars on curves of 10 degrees and under. For curves sharper than this, the screen must be drawn back from track a little. Dirty stone is thrown onto the screen from in front and the side, and clean stone is delivered back on berm, being piled high in a windrow, clear of the ballast line, so that in dressing, board is laid down on line, one line of stone is placed by hand, and dressing completed by drawing down stone with a fork against the board. (Note dressing, Figs. 1 and 4.)

An apron has been attached, which is pushed forward when sufficient stone has been placed on the berm, and remainder allowed to run between the rails. (Note Fig. 1, the apron of one side screen down for use and the other withdrawn.) Pan can still be used, if it is desired to take stone some distance. The screen is entirely backed with galvanized iron to collect the dirt, and opening being left at the proper place, which is closed by a door. When this door is opened, it acts as a chute delivering the dirt into a wheelbarrow. When closed the screen holds about a wheelbarrow-load of dirt, giving opportunity for exchanging the full for an empty wheelbarrow. When the screen is moved, one man raises each of the rear legs and one man pulls the front end along on ties.

When the screen is used in center ditch, the front horizontal legs are replaced by short vertical legs; the long rear adjustable legs are replaced by shorter adjustable legs, the door is removed as dirt is discharged directly into a pan placed under the screen, from which it is shoveled by a man with a long-handled scoop shovel into a wheelbarrow placed across the outside rail. (Of three methods of relieving the center screen pan, viz., scooping out, exchanging pans and catching dirt in sack, the first was found to make this man available for dressing up behind the screen by about one-third more time than the last two, as it requires only about six or eight scoopfuls to clean out the pan.) The apron is removed, as it is not used in center ditch, and the hood which formed the top of screen in its side position is thrown forward. In this position the screen progresses backwards, dirty ballast is thrown over the top and deflected down by the hood, clean ballast being left behind in the center ditch, and the dirt being dropped into the pan underneath. In moving this screen the two men behind it place the rear legs well forward in the direction of progress and pull screen forward, repeating this walking movement until the required distance has been covered. The pan beneath moves with the screen. The screen is let down flat on passage of trains.

IMPROVEMENTS SINCE LAST REPORT.

SIDE USE.—Apron for depositing clean stone on berm or in crib at will: change in horizontal legs and in the pitch of lower end of the screen, so that ballast on berm is left clear of the ballast line, from which position it can be drawn down against the board with minimum of labor.

CENTER DITCH USE.—Lower legs modified so that in yard use, where there is no place to dispose of or leave dirt standing open, it is dropped directly from screen into sack and left in the center ditch to the rear

Fig. 1.

Fig. 2.

Fig. 3.

to await removal by work train. Change of the legs also increases the speed of this screen by clearing cleaned ballast behind without the assistance of shovel.

GENERAL.—Use of scoops adopted instead of track shovels in center ditch and on berm, as this was found to increase speed by a large percentage. Track shovels must still be used in the crib, on account of limited space.

ECONOMICAL DISPOSITION OF STONE AND DIRT AND OPPORTUNITY FOR EFFICIENT ORGANIZATION MAKE RESULT POSSIBLE.

After a screen has been evolved which will clean the ballast satisfactorily, the entire problem remaining is to give it such form and to so organize the gang that from the time the dirty ballast is disturbed until the time the clean ballast reaches its resting place in the track, both stone and dirt progress in an orderly manner, without interference or back movement and the disposition of the stone is so arranged that the additional stone required occasioned by loss of volume in cleaning can be dumped directly into place from the car without handling, and each member of the gang has prescribed duties which do not interfere or depend on any other member of the gang. The pickers, shovelers and dressers have designated and uniform strips of ballast to work over, always moving in the direction of the progress of the gang and using, without an exception. one tool only.

STANDARD BALLAST SECTION USED IN CLEANING BALLAST.

Ballast in all cases is cleaned 12 in. below bottom of tie on berm and 6 in. below bottom of tie in center ditch, and to bottom of tie in crib. This line is indicated in Fig. 4, by heavy line "B." One crib on

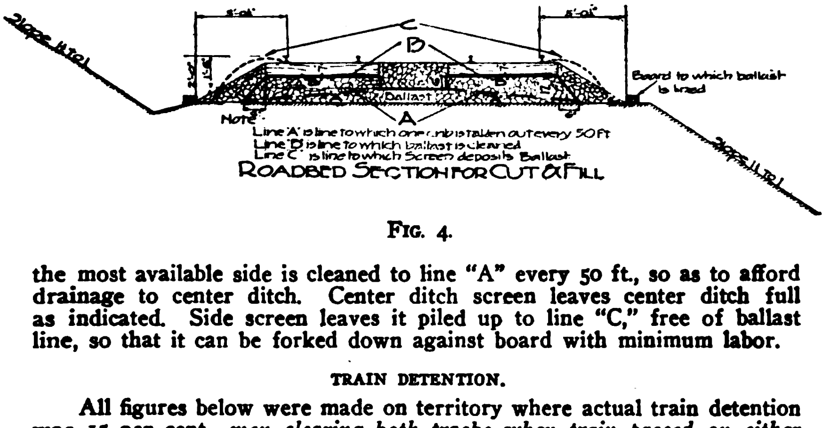


FIG. 4.

the most available side is cleaned to line "A" every 50 ft., so as to afford drainage to center ditch. Center ditch screen leaves center ditch full as indicated. Side screen leaves it piled up to line "C," free of ballast line, so that it can be forked down against board with minimum labor.

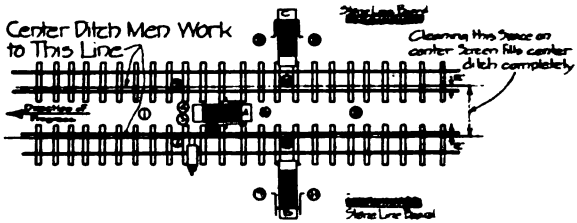
TRAIN DETENTION.

All figures below were made on territory where actual train detention was 15 per cent., *men clearing both tracks when train passed on either track, in accordance with safety rules.*

ARRANGEMENT OF SCREENS AND GANG ORGANIZATION FOR VARIOUS CLASSES OF WORK.

(a) See Fig. 2 for photograph and Fig. 5 for diagram. To clean standard depth and dress up ballast complete where track is not to be raised, six men operate screen "A," cleaning center ditch and cribs 12 in. inside of inside rail, of each track, so as to get ballast enough to fill center ditch complete; three men each operate screens "B" and "C," clean-

ing berm and remainder of cribs not cleaned on center screen; men numbers 11 and 12 are the architects of the berms. They take from their wheelbarrows of dirt enough for dressing purposes and waste the rest: they level up the berm for reception of stone line, haul forward dressing board, pin it down; lay one line of stone by hand, and dress down the ballast from the position in which screen has left it, to standard section. These men quickly learn how much stone is required on berm and pull down apron, allowing the rest to go between rails. A slight shower of new stone from a Rodger ballast car, between rails, completes dressing.



GANG ORGANIZATION.

Cleaning ballast where track is not to be raised 12 in. below tie on berm. 6 in. below tie in center ditch, and to bottom of tie in crib, cleaning one crib every 50 ft. deep enough to drain center ditch. Dress up berm to hand-laid ballast line and dress center ditch to standard, leaving cribs between rails partially empty for future dumping of ballast.

Output of this gang 200 ft. of double track per 10-hour day. This supposes putting dirt into wheelbarrows, additional men being required for long haul of dirt.

Men.	Duties.	Tools.
No. 1	........Picks for 2, 3, 4 5	1 Pick
No. 2	........Shovel on center screen	1 Track Shovel
No. 3	........Shovel on center screen	1 Scoop Shovel
No. 4	........Shovel on center screen	1 Scoop Shovel
No. 5	........Shovel on center screen	1 Track Shovel
No. 6	........Shovels out of pan onto wheelbarrow and dresses up behind screen	1 Long-handle Scoop Shovel 1 Ballast Fork 2 Wheelbarrows
No. 7	........Shovel on side screen	1 Scoop Shovel
No. 8	........Shovel on side screen	1 Scoop Shovel
No. 9	........Shovel on side screen	1 Track Shovel 1 Pick
No. 10	........Shovel on side screen	1 Track Shovel 1 Pick
No. 11	........Dress ballast behind side screen and empty wheelbarrow	1 Track Shovel 1 Ballast Fork 1 Pick
No. 12	........Same as No. 11	1 Track Shovel 1 Ballast Fork 1 Pick
No. 13	........Foreman	

Total—13 men

Total of Tools—
5 Picks
6 Track Shovels
1 Long-handle Scoop Shovel
3 (or more) Wheelbarrows, depending on haul
2 Boards 16 ft. by 1½ in.

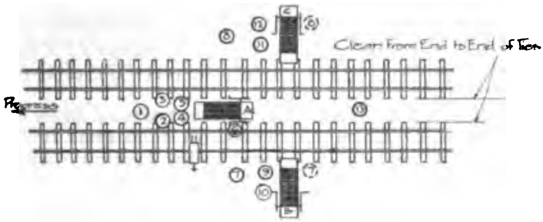
FIG. 5.

Progress 200 ft. per 10-hour day, track on 12-ft. centers; cost per mile of double track, foreman $77 per month and twelve laborers at $1.75 each per day, total $622.

(b) (See Fig. 5.) To clean standard depth without dressing where track is to be raised, same as "A," except that man 12 is eliminated, no dressing being done; man 11 empties wheelbarrow for both side screens

and assists in moving both screens and smooths down ballast on both berms with fork. In this case, sufficient stone would be run between the rails from side screen to raise the track on, leaving the berm shy, which will facilitate the renewal and re-spacing of ties.

Progress 200 ft. per 10-hour day, track on 12-ft. centers. Cost per mile of double track, complete: Foreman, $77 per month; 11 laborers at $1.75 per day each, total $576.



GANG ORGANIZATION.

Cleaning ballast 12 in. below tie on berm, 6 in. below tie in center ditch—cribs not being cleaned except one every 50 ft. deep enough to provide drainage for center ditch. A shower of ballast between rails will be necessary to complete dressing of berm and center ditches.

Output of this gang 475 ft. per 10-hour day of double track. This supposes putting dirt in wheelbarrows. Additional men being required for long haul of dirt.

Men.	Duties.	Tools.
No. 1	........Picks center ditch end to end of ties	1 Pick
No. 2	........Shovel on center screen	1 Scoop Shovel
No. 3	........Shovel on center screen	1 Scoop Shovel
No. 4	........Shovel on center screen	1 Scoop Shovel
No. 5	........Shovel on center screen	1 Scoop Shovel
No. 6	........Shovel out pan into wheelbarrow	1 Long-handle Scoop Shovel
No. 7	........Empties wheelbarrow, picks ahead of side screen, levels up berm	1 Wheelbarrow 1 Pick 1 Track Shovel
No. 8	........Same as No. 7	1 Wheelbarrow 1 Pick 1 Track Shovel
No. 9	........Shovels on side screen	1 Scoop Shovel
No. 10	........Shovels and picks side screen	1 Pick 1 Scoop Shovel
No. 11	........Same as No. 10	1 Pick 1 Scoop Shovel
No. 12	........Shovels on side screen	1 Scoop Shovel
No. 13	........Foreman	

Total—13 men

Total of Tools—
- 5 Picks
- 9 Scoop Shovels
- 1 Long-handle Scoop Shovel
- 2 Track Shovels
- 2 Wheelbarrows

Fig. 6.

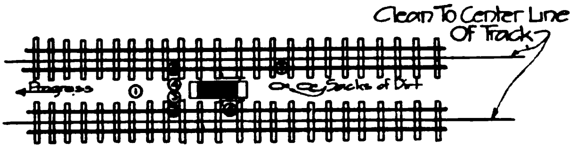
(c) (See Fig. 6.) To clean to standard depth on berms and center ditch only, no cleaning being done in cribs, no dressing except a little smoothing up, as more ballast will be required, whether track is raised or not. This is showered between the rails from Rodger ballast car and shoveled in center ditch and on berms in dressing up; six men operate screen "A" and three men each screens "B" and "C." This method is approved by some important roads; the cribs being cleaned in connection with tie renewals.

Progress 475 ft. per day, track on 12-ft. centers. Cost per mile of double track, complete: Foreman, $77 per month; 12 laborers at $1.75 per day each, total $262.

CLEANING BALLAST IN YARDS.

In yard work it is obvious that the disposal of dirt is more difficult than out on the line, where it can be thrown over the bank or used in dressing. Even in territories on the line where we have grassed slopes and would not throw the dirt down the bank on that account the dirt can be left in windrow along the shoulder and loaded up on work train, but this cannot be done in large yards, as the clean ballast occupies all the available space. This may also be true on main-track territory, which is grassed, and there is no room to leave dirt temporarily. An attachment has been provided for this class of work in the shape of a spout, which is attached by bolts beneath the screen, and delivers the dirt into a common sack.

There has been provided an arrangement which shuts off this spout during the exchange of sacks. A sheet-iron slide rests in the bottom of the center ditch with front end upturned, sled fashion. This moves with



GANG ORGANIZATION.

Cleaning in yards from center of track to center of track on screen in center ditch—one or more screens with the same organization for each can be added for adjacent center ditches, and worked by same Foreman. Clean 6 in. below ties in center ditch and to bottom of tie in crib dress up center ditch complete, leaving deficiency of stone between rails for future dumping of ballast. Leave dirt sacked behind in center ditch.

Output of this gang 190 ft. complete in 10-hour day. This supposes sacking all dirt and leaving in center ditch behind.

Men.	Duties.	Tools.
No. 1	Picking from center line to center line	1 Pick
No. 2	Throwing on screen	1 Track Shovel
No. 3	Throwing on screen	1 Scoop Shovel
No. 4	Throwing on screen	1 Scoop Shovel
No. 5	Throwing on screen	1 Track Shovel
No. 6	Sacking dirt, dressing ballast	Sacks, String and Ballast Fork
No. 7	Foreman	
Total—6 men		

Total of Tools—
1 Pick
2 Track Shovels
2 Scoop Shovels
1 Ballast Fork
Sacks and String

Fig. 7.

the screen, being brought along by the front legs. Sack to receive dirt is set on this slide, hooked up around the spout by two sharp hooks and filling proceeds. When full, one man ties up sack, pulls another sack under spout, dumps filled sack over on side, under low end of screen and it passes out behind screen as latter is moved, leaving sacked dirt in the center ditch to be picked up by work train. Man doing sacking also dresses up behind screen. These sacks can be bought by the thousand at a small cost. Two classes of work are shown for yards:

(a) (See Fig. 3 and diagram 7.) Cleaning 6 in. below tie in center ditch and to bottom of tie in crib, half-way on each adjacent track. Man No. 1 picks from center line to center line of tracks; men Nos. 2, 3, 4

and 5 shovel onto the screen and man No. 6 sacks dirt. Center ditch is filled complete, and space left between rails to be supplied by shower of new stone from Rodger ballast car. Excess stone not required in center ditch is caught in pan and carried over rail into cribs.

Progress 190 ft. per 10-hour day, 12-ft. centers (exclusive of switches). Cost per mile: Foreman, $77 per month; six laborers, $1.75 each per day, total $363.

The above figures are based upon 15 per cent. detention. In yards of heavier movement, they should be increased accordingly.

(b) (See Fig. 6.) Cleaning in cribs only to bottom of tie. The center ditch organization shown in Fig. 6 is applicable here, excepting man No. 6 sacks instead of shovels. This gang consists of foreman and six men. Leaving dirt in center ditch behind sacked complete.

Progress 475 ft. per 10-hour day, 12-ft. centers (exclusive of switches). Cost per mile: Foreman, $77 per month; six laborers at $1.75 per day each, total $145.

The above figures based on 15 per cent. detention.

Organizations "A" and "B" may be doubled or tripled in yards by putting screens in adjoining center ditches, to be worked abreast under the same foreman.

SHALL WE CLEAN THE BALLAST IN THE CRIBS BY EXTRA OR REGULAR SECTION GANGS?

Railroads representing a large mileage are requiring that when regular tie-renewals are made, the ballast in the crib each side of the new tie be cleaned. Supposing the life of the tie to be eight years, this cleans the crib on an average of once in four years. If then the center ditch and berms are cleaned every two or three years, we have an ideal condition. We have shown that this can be done at a cost of $262 per mile. All cleaning could then be done by the regular section gangs. A gang consisting of a foreman and 12 men, equipped with three screens, moving at rate of 475 ft. per day, or a mile of double track every twelve days, should, along with their regular work, clean a mile per month. On a section of four miles of double track, complete cleaning of center ditch and berms could be expected every three years, the tie-renewals taking care of the cleaning of the cribs every four years.

SCREENS USED IN CONNECTION WITH TIE RENEWALS BY REGULAR SECTION GANGS.

For this purpose one screen is used, equipped with fixtures for side of track use; three men operate this screen, ahead of tie renewals, going only so far as ties will be renewed that day. One man picks on each side of tie to be taken out and disposes of dirt from screen. Two men follow, one shoveling out each crib adjacent to tie to be removed, throwing the dirty stone on the screen. Dirt is delivered by screen into wheelbarrow and clean stone is caught in pan at foot of screen. This is pulled over rail and dumped from the pan close along the edge of the crib to be filled, and the cleaners proceed to the next crib. The men renewing ties then proceed with the tie renewals, working in pairs, withdrawing old ties, putting in new and tamping up. A few trains are allowed to pass over the new tie before it receives its final tamping. The cleaned stone which has been left laying along the edge of the crib is forked into crib, and the renewal is complete. By this method of combining the tie renewals and cleaning, the one shoveling out cribs answers both purposes and a saving is made which the use of screens greatly increases.

DETAILS OF COLLAPSIBLE
STONE BALLAST SCREEN.

DETAILS OF COLLAPSIBLE
STONE BALLAST SCREEN.

DISCUSSIONS

DISCUSSION ON RULES AND ORGANIZATION.

(For Report, see pp. 65-70.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RULES AND ORGANIZATION.

J. B. BERRY.
G. D. BROOKE.
H. M. CHURCH.
C. H. FISK.
L. C. FRITCH.
A. J. HIMES.
C. P. HOWARD.
C. E. LINDSAY.
WILLIAM MCNAB.
H. R. SAFFORD.
FRANCIS LEE STUART.

The President:—Mr. G. D. Brooke, Chairman of the Committee, will present the report of the Committee on Rules and Organization.

Mr. G. D. Brooke (Baltimore & Ohio):—The report consists roughly of two parts, a few revisions of the matter which has already been adopted by the Association; these revisions are not extensive; then a set of instructions or rules to govern the chiefs of parties on surveys and construction work. In formulating these new rules the Committee has attempted, as far as possible, to follow out the same general line of thought that has been followed in formulating the rules for the maintenance of way organization. I would offer a motion that the various rules submitted and the revisions be read, in order to have discussion of them.

(Mr. Brooke then read the first rule.)

Mr. Brooke:—I would like to add here that the sub-committee on Revision of the Manual thought it wise to introduce something into our rules at this time bearing on the safety question which is so prominently before the railroads of the country, and this revision of the general notice and revisions of certain rules under the different supervisor and foreman headings resulted. I offer the motion that that revision be adopted.

Mr. H. M. Church (Baltimore & Ohio):—I would like to refer to the fourth sentence, reading, "They must move away from tracks upon approach and during passage of trains, and, so far as practicable, prevent the public from walking on tracks or otherwise trespassing on the right-of-way." It does not seem to me that it quite covers the situation. I move the sentence be changed to read, "On approach of trains employés who are working on and about tracks must move to places of safety, and, so far as practicable, prevent the public from walking on tracks or otherwise trespassing on the right-of-way, and also warn and serve notice on those habitually trespassing." I think at places where there is constant trespassing on railways, some notice should be given.

Mr. Brooke:—The only revision which is offered by the Committee is simply the addition of one sentence to that paragraph of the general notice, which has been adopted by the Association. It does not offer that entire paragraph, so to make that revision would mean to go back of this Committee's report at this time and be a revision of the matter which has been adopted. The Committee thought that this revision simply

meant calling attention to the safety regulations. As I recall it, at the time this rule was promulgated, it was considered specific enough for the general notice and did not intend to go into such detail as Mr. Church has in mind. The view of the Committee is that that would be covered in rules which follow, or in more specific rules of individual companies.

Mr. Church:—The point I want to make is in regard to employés moving away from tracks—that is hardly practicable, and in yards would not apply. If employés were required to move away from tracks in yards, they would be obliged to move to clear running tracks, and that would not be practicable on a four-track railroad. The place of safety should be specified in detail.

Mr. Brooke:—That is true; but the Committee does not think that the general notice is the place to cover that. That would be covered specifically in the safety regulations of the company.

Mr. W. I. Trench (Baltimore & Ohio):—Why should the wording state specifically that men should get off all the tracks, when we know it is not possible to get off all the tracks on all occasions? We should say all "running tracks," or modify it in some way so that it will be possible to do what the instructions tell us to do.

(Mr. Church's motion was lost.)

Mr. C. E. Lindsay (New York Central & Hudson River):—In regard to rule 41, will the Committee omit the words at the end of the proposed rule, "of the road"?

(The suggestion was accepted by the Committee.)

(Rules 13 and 18 were adopted as read.)

Mr. H. R. Safford (Grand Trunk):—I think that Rule 17 is a good rule. I presume the intent is to make the section force feel a certain responsibility for keeping the portions of the interlocking plants that pertain to the track in good order without being called on specially to do so. It seems to me in view of the fact that there must be complete co-operation between the section force and the men in charge of the interlocking plant, and the fact that the interlocking man must not be relieved from the responsibility for seeing that this work is done, an addition to that rule, expressing that co-operation, would be a valuable thing, in order that it may not be understood to relieve the local interlocking plant force from some of that responsibility. It seems to me it could be expressed in such a way that when the section foreman left a man at the plant, this man should be under complete direction of the towerman or maintainer.

Mr. Church:—Would the Committee consider the word "interlocking" to cover taking care of all pipe lines, derails, etc.?

Mr. Brooke:—The Committee feels that the word "interlocking" would not cause any misunderstanding and would be interpreted as covering derail pipe lines. There might be other classes of pipe lines, underground pipe lines, which would not be affected; whereas, if we left out the word "interlocking" it might be applied to other lines than track appliances.

As to Mr. Safford's suggestion, the Committee thinks that arrangement would probably mean a division of authority affecting the section foreman's force, putting some of his men at certain times under the charge of the signal maintainer, who might be inclined to carry his authority too far. These rules apply only to track foremen, and rules which will probably be written later, governing maintainers, will cover that point.

Mr. Safford:—The principal point is, there should be something to require co-operative effort between the section foreman and the interlocking force.

Mr. Brooke:—The Committee will take that point into consideration in connection with next year's work.

(The amendment to Rule 17 was carried.)

Mr. Brooke:—The Committee has formulated rules for the government of employés of the construction department, the first portion of which is the general notice, which is in accordance with the notice applying to the maintenance of way department, previously adopted. There are some sections of the general notice which might not seem to apply directly to survey parties, but when these parties are working around tracks they will be found to apply pretty generally; also where construction work is being done along running tracks, where there is danger of blocking the traffic.

William McNab (Grand Trunk):—I think in this general notice we should be consistent, because it is going into the Manual. Rules 4 and 11 are not expressed in quite the same terms. Rule 4 states that employes must exercise care and watchfulness to prevent injuries to themselves, other employés and the public. Rule 11 says that employés must be courteous to fellow-employés and patrons of the road. I think if the Committee would change the wording to "fellow-employés and the public" it would be in better form. I would not like to see the Association go on record as limiting the range of courtesy.

Mr. Brooke:—The Committee will accept that suggestion.

Mr. C. H. Fisk (Consulting Engineer):—Rule 10 reads, "Employés must not absent themselves from duty." Could we not add "without authority"?

Mr. L. C. Fritch (Canadian Northern):—The words "without permission" at the end of that rule would cover that.

Mr. Brooke:—The Committee will accept that.

(The rules under "General Notice" as amended were adopted.)

(Mr. Brooke read the rules under "Organization.")

Mr. Lindsay:—Will the Committee accept the removal of the word "periodical" in rule 2?

Mr. Brooke:—Yes; we will accept that.

(Mr. Brooke read rules 3 and 4.)

Mr. Lindsay:—It seems to me that the chief of the party would be as responsible for the improper conduct of the party as for the proper conduct of the party. Will the Committee accept the omission of the word "proper"?

Mr. McNab:—I do not think it is possible for any man to be responsible for the improper conduct of his men, unless the hours are specified that conduct is to be supervised.

Mr. Brooke:—The Committee will accept Mr. Lindsay's suggestion.

Mr. C. P. Howard (Consulting Engineer):—Rule 4 raises a question, I do not know how it is provided for, that the chief of the party must know that each man is competent to do the work required of him. Suppose he has not appointed the man, as is frequently the case?

(Mr. Brooke read rules 5, 6, 7, 8, 9, 10 11 and 12.)

Mr. J. B. Berry (Rock Island Lines):—If it is permissible, I would like to go back to rule 5 and suggest to the Committee that they should put the word "instructions" after the word "prescribed," so that it shall read, "They shall conform to the prescribed instructions, standards and plans in the execution of work under their charge." Anyone in giving out instructions has to go by standards and plans, and he is required to carry those out very carefully.

Mr. Brooke:—The Committee will accept that revision and insert the word "instructions."

Mr. L. C. Fritch:—I would like to suggest to the Committee that the word "prescribed" be omitted, because some of the work may not be prescribed, but may be given verbally.

Mr. McNab:—"Prescribed" will come in all right. Instructions may be given before they are written.

The President:—How do you wish it to read, Mr. Fritch?

Mr. L. C. Fritch:—I would omit the word "prescribed" and have it read, "They shall conform to the instructions and plans in the execution of work under their charge."

Mr. A. J. Himes (New York, Chicago & St. Louis):—I would like to protest against the insertion of the word "instructions." It seems to me to be wholly impertinent that we should formulate a rule saying that any body of railroad men should conform to instructions. The very idea of the preparation of instructions implies that they will be conformed to.

Mr. L. C. Fritch:—I would like to go back to rule 6 and change the last part of the sentence to read, "and see that these are properly cared for and used;" I think it would be better than to end that sentence with a preposition.

Mr. Brooke:—The Committee will accept that.

A Member:—I move that rule 10 be eliminated and that rules 11 and 12, as written in the report, be made to read rules 10 and 11. My reason for that is that I think we should not bind the chief of party to such rigid lines as are here required; that he should be allowed a certain amount of flexibility in handling his party, and if the work requires his being in charge, he is the one to judge of that. I doubt whether we should lay down such rules.

The President:—The Committee accepts that suggestion.

(Rules as amended were adopted.)

Mr. Brooke:—The Committee has submitted a report to the Board of Direction on the question of the study of the science of organization,

as instructed. While the information on this subject that has been collected and is not very extensive, the Committee feels that there is quite a large field and that a great deal of good can be done by a proper study of the science of organization. There is an indication that in a great many parts of the country more attention is being given to this phase of organization; more thought is being given to organization, to the proper selection of all grades of employés, their education and proper compensation, and results are apparent in some quarters already. If the Board of Direction sees fit to instruct the Committee to continue this study, the Committee will have to depend upon the members of the Association for the information with which it will have to work, and the success of the study will be determined by the replies to the circulars or questions which the Committee may send out, so that the matter rests in the hands of the individual members of the Association as much as in the hands of the Committee, and the Committee hopes for the hearty co-operation of all the members.

Mr. L. C. Fritch:—Before this Committee is dismissed, in behalf of the Committee on Outline of Work, I would like to ask that the matter of instructions for next year's work be considered. In some cases the committees have made recommendations, but in others no recommendations have been made. It will greatly aid the Committee on Outline of Work if we can get the specific recommendations of the committees; then I think, too, this matter of instructions to committees is of such vital importance to the Association that the convention at large should have something to say about it. If there is a member who has some live subject to suggest, it might be well to have the suggestion made. I ask that the Committee on Outline of Work be given all of the assistance in this matter possible, in order that we may select live topics in our instructions to committees for next year's work.

The President:—The Board of Direction, at its meeting yesterday, decided that they desired two things done: First, that each committee should recommend an outline of work for one, two, three, four and five years in the future. Many committees have done this; a few have failed to do so. Consequently, the Board desires the general membership to make suggestions at this convention as to what work should be done under the head of each committee. Now, if you have in mind any question which should be studied, or any outline of work which should be prosecuted over a series of years, the Board, and especially the Committee on Outline of Work, desires you to offer those suggestions at this time. Has anybody any suggestion to offer as to what work the Committee on Rules and Organization should undertake for next year in addition to that which is already suggested? The Board is so well pleased with the preliminary work submitted by the Committee respecting the study of the science of organization that it has decided that the study will be continued, and no doubt a report from this Committee will be printed within probably the next year or two. In closing this discussion the Board desires to compliment the Committee for its valuable and faithful work in connection with this report. The Committee is now dismissed.

DISCUSSION ON SIGNALS AND INTERLOCKING.

(For Report, see pp. 71-100.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNALS AND INTERLOCKING.

C. C. Anthony.	J. B. Jenkins.
J. L. Campbell.	C. E. Lindsay.
W. A. Christian.	J. C. Mock.
H. M. Church.	L. S. Rose.
L. C. Fritch.	H. R. Safford.

The President:—The Chairman of the Committee, Mr. Thos. S. Stevens, had expected to be present, but is detained by illness. The report will be presented by the Vice-Chairman, Mr. C. C. Anthony.

Mr. C. C. Anthony (Pennsylvania Railroad):—Under the first subject assigned to the Committee, namely, "Report on Economics of Labor in Signal Maintenance," the Committee has prepared a report, which you will find on page 71 of Bulletin 162, and offers it as a progress report, with the request that the subject be continued. I doubt if it is desirable to take the time to read it. If there is any discussion on what we have here, we should be glad to have it for the guidance of the Committee in its future work.

With reference to subject (2) Formulate and submit requisites for switch indicators, including method of conveying information on condition of the block to conductor and engineman, the Committee has done some hard work, and has made the discovery that this is an interesting subject and one on which there is a good deal to be said. They are not, however, ready to make a report at this time, and simply report progress. The third subject was to investigate on automatic control.

The Committee submits, beginning at the bottom of page 73, some matter on the effect of treated ties on track circuits.

Since this matter was printed some further investigations have been made on zinc-treated ties, particularly, which brings out some very interesting results, and the chairman of the Committee sent me a copy of the matter on that subject, which, with your permission, we will add to the report as it is printed in the Proceedings.

If there is any discussion on the matter of track circuits, we would be glad to have it.

Under the heading "Revision of Manual," the Committee has compared the present symbols as shown in the Manual with those at present in use by the Railway Signal Association. These symbols were adopted by the Railway Signal Association possibly two years ago and have been in actual use on signal plans for at least a couple of years. They include certain symbols taken from the Manual of this Association, which are applicable to the case. For example, on page 83, the symbol

for water column was taken from the Manual. These symbols relate particularly to signal and circuit devices, which have been originated by a joint committee of the Railway Signal Association and a Committee of this Association.

The Committee recommends that these symbols be placed in the Manual as a substitute for the signal symbols now in the Manual.

Mr. L. C. Fritch (Canadian Northern):—With the permission of the convention, I would like to go back to the subject of track circuits. It is quite important, in view of the extended use of treated ties, that some definite recommendation should be made as to the length of track circuits when treated ties are used. The Committee has gone into this subject very exhaustively, and it might be well for them to give us some recommendation as to what to do with our track circuits in case a certain class of treated ties are used and a certain number of ties per mile are used.

Mr. Anthony:—The Committee will be glad to take up that subject in the work of next year.

Mr. C. E. Lindsay (New York Central & Hudson River):—The subject of track circuits is very important. We found in certain locations that the accumulation of brake-shoe dust on the tracks has a greater influence on the signals than the dirty condition of the track, the ballast, or the use of special ties.

I have compared the symbols shown on pp. 81 and following, and have found some differences between those shown here and those shown in another Bulletin, for instance, mileposts. I did not have an opportunity to compare them with the Manual, but there are some differences which ought to be reconciled before this list is substituted for that in the Manual.

Mr. W. A. Christian (Chicago Great Western):—Referring to Mr. Lindsay's remarks regarding the symbol for mileposts, as shown in Bulletin 162 and that in the Manual, it seems to me, if the Interstate Commerce Commission are going to accept our symbols as shown in the Manual, we should include the symbols the Interstate Commerce Commission is using. The selection of symbols is coming up in the report of your Committee on Records and Accounts. In regard to highway crossings, the symbol for that is different in the Manual from the symbols submitted by the Interstate Commerce Commission. These symbols should be reconciled before being adopted.

Mr. Anthony:—I move that the symbols on pp. 81 to 90, inclusive, be substituted for the signal symbols now in the Manual.

Mr. H. M. Church (Baltimore & Ohio):—This Committee should confer with the Committee on Records and Accounts and reconcile any differences which may exist in the symbols submitted. That is important, in my opinion, inasmuch as the Interstate Commerce Commission has specified the use of the symbols recommended by this Association in connection with the valuation of railways.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I think we should adopt the symbols submitted by this Committee for signals and interlocking, and also adopt the symbols submitted by the Committee on Records and Accounts, so that we will have something at the end of this convention to go on.

Mr. Anthony:—The Committee will accept Mr. Rose's suggestion and make the motion read: That those symbols peculiar to signaling and interlocking be adopted and substituted for those on pp. 219 to 225, inclusive, of the Manual, edition of 1911.

Mr. Church:—There is one specific case which may lead to confusion. The symbol for two-way bolt lock, as recommended by this Committee, is almost identical with the symbol for road crossing submitted by the Committee on Records and Accounts, and it seems to me that should be straightened out.

Mr. Anthony:—The answer to that is that each will appear on the plan in an entirely different place from the other, and it is very doubtful if there could be any conflict in practice.

Mr. J. L. Campbell (El Paso & Southwestern):—We have an important matter here. It is undesirable to represent one thing by more than one symbol. A symbol for the milepost should be the same wherever found, be it in location, construction or maintenance records. Confusion will result if one thing is represented by more than one symbol.

The President:—The differences between the recommendations of the Signal Committee and the recommendations of the Records and Accounts Committee can be reconciled without any difficulty.

The motion is that the Manual be amended and that the symbols on pp. 81 to 92, subject to such modifications as are necessary in order to harmonize the recommendations of the Committee on Signals with those of the Committee on Records and Accounts, be adopted.

(Motion carried.)

Mr. Anthony then called attention to Appendix A, and said: This, we think, is valuable information inasmuch as several States have taken joint action in the matter, and it is advisable that the rules be in our literature—the rules governing the construction, maintenance and operation of interlocking plants as adopted by the States of Wisconsin, Illinois, Indiana, Minnesota, Missouri and Iowa. The Committee has not had the opportunity to analyze the rules in detail, but they were prepared by persons representing the Commissions in those States, who consulted very freely with signal engineers of many of the roads affected.

Mr. L. C. Fritch:—These rules have been adopted by the railroads in all the States named, have been found to be very reasonable, and I believe we could accept them without any reservation.

The President:—Are there any remarks in connection with the Appendix? If not, we would be glad to have the Committee recommend what work should be taken up next year. The Committee states it will give this matter consideration and submit its recommendation later. Have the members of the Association any suggestions to offer as to the

future work of this Committee? This question is one of first importance, and any study which the Committee makes should have reference to the work for a series of years.

You will notice that the Committee submits for the information of members some observations respecting economics of labor in signal maintenance. The membership should express itself in reference to this study, because it is one which should be prosecuted continuously for several years to come.

Mr. Anthony:—There is considerable difference of opinion in the Committee as to what to do with the subject, how to approach it, and what to report on it. If there is no discussion directly on what we have printed here in the Bulletin, we should be glad to get suggestions for our further work.

Mr. H. R. Safford (Grand Trunk):—As a member of the sub-committee of the Track Committee having this particular subject in hand, it seems to me that there is a good deal that can be discussed between the two committees, the Signal Committee and the Track Committee. We have only made a start on this subject of the Economics of Track Labor. Naturally, one of the first things we did was to make inquiry as to the extent to which this idea had been put into effect by the railroads and the information which we have so far received is that combined work has been taken in hand by two or three railroads, and in the particular instance in mind it has been in connection with the maintenance of the signal system and other work in connection with signals. We have made so little progress, it is hard for us to add much of value at this time to the general subject, but I suggest there should be some definite, systematic and co-operative arrangement between the Signal Committee and the Track Committee on this particular subject. This appears to be the only idea which has been taken up in the direction of combining forces, and if it meets the view of the Signal Committee that there should be a sub-committee appointed by it to co-operate with the sub-committee of the Track Committee, I am sure such co-operation would be helpful to both. There is a great difference of opinion about many features. Being the only branches of the service combined in an experimental way, it leads me to the suggestion that there be some systematic co-operative method.

Mr. J. B. Jenkins (Baltimore & Ohio):—I endorse the suggestions of Mr. Safford as to co-operation between the sub-committee on Signals and Interlocking and the sub-committee on Track.

The President:—When we outlined our committee work two years ago, we included this subject of economics in labor, and we looked back over the fifteen years' history of the Association and found that much study had been given to the technical side of the matters of design, but that very little consideration had been given to the broader question of the economics of labor. We all know that about 55 per cent., and in some places between 50 and 60 per cent., of the expenses of the railway are consumed in the labor charges, and the importance of this question is reflected by those statistics.

If the Engineer is ever going to assert himself in connection with the broader questions of the railway business, he will have to study the question of economics. This subject has been defined as the social science of business, and it does seem to me that the object of our Association is not alone to consider the design of appliances, respecting the construction and maintenance of railways, but it is as well to consider the broader economic features. The Engineer is peculiarly educated and fitted for making this study and it is the hope of the Board of Direction that all of our committees will consider this broad question of economics of labor and that the membership at large will submit its observations from time to time in writing, so that they may be included in the Bulletin.

Mr. J. C. Mock (Michigan Central):—It occurs to me in the co-operation of committee work it may be well for this Committee to work also with Committee on Rules governing the Track Department and Signal Department. I think that is in line with Mr. Safford's suggestion.

The President:—The Board has already complimented this Committee for faithful attendance, not only at the convention, but upon its work. We desire to thank you once again for your loyalty to the interests of the Association.

DISCUSSION ON YARDS AND TERMINALS.

(For Report, see pp. 101-148.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON YARDS AND TERMINALS.

G. D. Brooke.
A. E. Clift.
Maurice Coburn.
L. A. Downs.
E. H. Lee.
C. E. Lindsay.
B. H. Mann.
A. Montzheimer.
W. B. Scott.
Francis Lee Stuart.
E. B. Temple.
W. I. Trench.

The President:—The next report will be that of the Committee on Yards and Terminals. In the absence of the Chairman, Mr. C. H. Spencer, the report will be presented by Mr. E. B. Temple, the Vice-Chairman.

Mr. E. B. Temple (Pennsylvania Railroad):—Mr. Spencer has left the Washington Terminal Company and has been appointed Assistant District Engineer of the Valuation Board of the Government. He wrote me that he regretted very much that he could not be with us to-day, as it is the first time he has been absent from one of these meetings for several years. We should congratulate ourselves upon the fact that men like Mr. Spencer and our President, Mr. Wendt, should be called by the Government to aid in the work of this very important commission, and I know the work they have done in this Association will be of great assistance to them in their new positions.

(Mr. Temple then read the outline of the subjects assigned to the Committee, and said:)

We are not this year prepared to make any report on subject No. 1, "Typical Situation Plans of Passenger Stations," although progress has been made, and the Committee hopes to have its report ready in another year. Last year three methods of critical analysis of working capacity of passenger terminals were submitted, one by Mr. Lane of a method devised by Belgian engineers, another by the Pennsylvania Railroad, showing the method they pursued in studying the situation at Broad Street Station, Philadelphia, where they are now electrifying, and a third submitted by Mr. Mann, termed the co-ordinate system, and we are endeavoring to have that method worked out at some important terminal to see the results.

A very thorough report has been made on subject No. 2, "Mechanical Handling of Freight." It deals with the telfer, gravity, chute and other systems, and describes the methods of handling in this country, as well as abroad, under the different systems. Considerable space is given to the report on hump yards, of which Mr. Montzheimer was the sub-committee chairman, and a yard at Winnipeg on the Canadian Pacific is discussed in detail.

The fourth subject was "Report on Track Scales." This matter is undergoing considerable change in this country to-day and many of the railroads are required to rebuild their scales and get them up to date. This Committee is not quite ready to make a report. Committees No. 1. on Passenger Terminals and No. 4 did not think it advisable to make a preliminary report for introduction in the general report on account of the space which the Association has given us on reports on mechanical handling of freight and hump yards. We have no recommendations to be incorporated in the Manual this year, but if the Committee is continued and asked to investigate the subjects which are not yet completed, they hope to have by next year a number of recommendations.

I wish to express my appreciation as an officer of the Pennsylvania Railroad of the valuable information that is contained in the Manual and in the reports of the various committees. I don't know of any document printed that gives more valuable engineering information than is contained in the Manual and the reports of this Association.

The President:—We will take up the first question, "Report on Typical Situation Plans of Passenger Stations," etc. Mr. Mann, chairman of the sub-committee, will you kindly discuss that question?

Mr. B. H. Mann (Missouri Pacific):—The thought on the analysis of the capacity of passenger stations is that something should be devised somewhat along the lines of the present methods of analysis of the line. When the question comes up as to the capacity of the line, the time at terminals, the meeting points, the solution is reached quickly and reliably by "stringing the schedule on the chart." A similar method has not yet been generally applied to a terminal. The terminal situation is often worked up by, you might say, the rule of thumb. The Committee feels, after a study of two years, that there should be no reason why some uniform method cannot be arranged for application to a congested passenger terminal. This year's study has been along the line of following up what was done last year. It may take a year or two years. The Committee feels that it should now apply some of the methods studied to present terminal situations and see how they work out.

The President:—The question is now open for general discussion. There are no recommendations, but the Committee would be very much helped by having your suggestions. If there is no discussion we will call on the chairman of the sub-committee on the developments in the handling of freight by mechanical means. The report of this Committee is certainly along the lines of scientific management and should give rise to discussion.

Mr. Clift, we would like to hear from you as chairman of the sub-committee.

Mr. A. E. Clift (Illinois Central):—Mr. Chairman and gentlemen of the convention: As is indicated by the Committee's report on the mechanical handling of freight, while considerable progress has been made in this and other countries, same has been confined mostly to commodities and articles of uniform size. The greatest difficulty encountered

in attempting to handle L.C.L. freight being the various sizes of packages, etc., thereby making the subject a very serious one, and at this time impossible to arrive at any definite conclusion. There is no question, however, but what this is a subject of vital importance to the railroads of the country and one in which a very great saving can be made.

The President:—Mr. Lee, will you please favor us with a discussion of this question?

Mr. E. H. Lee (Chicago & Western Indiana):—I do not desire to go into a general discussion of the report of this Committee. It is certainly of fundamental value to the railroads that the work which the Committee is doing should be done thoroughly. As, perhaps, some of the members may know, I have been engaged for some time past in an investiagtion of certain phases of the work, including some kinds of mechanical handling, which the Committee also covered to some extent, and I would be unable to add at this time anything over and above the views stated in an article in the last number of the Bulletin regarding this particular angle of the matter. It is an important subject. It occurs to me that other questions which are not so fundamental, and which involve neither as great an expenditure of money, nor as necessary and important a place in the operating of a railroad; have often received more attention in the past than this particular subject. This is easily explained. While congestion has been constantly increasing for many years under the old methods of freight handling, it has been a gradual increase, and in few places have the limits of the present methods been reached. I would not wish to express any hard and fast opinion as to the mechanical handling of L.C.L. freight, but am perfectly willing to express a tentative opinion regarding the matter.

The investigation which we have made has led us to believe that a good many of the claims made for mechanical handling cannot be substantiated. Claims for certain devices can be backed up by experience; certain devices are exceedingly valuable in a special way, but I question as to whether in the strictly mechanical handling of L.C.L. freight any method can be devised which will make good the claims made for mechanical handling, that is, without decreasing capacity and without increasing cost, unless this mechanical handling be reduced to some of the fundamentals.

One particular phase of the subject has impressed me radically. It seemed to stand out when I first considered the question; the fact that, as to mechanical means for the handling of L.C.L. freight, the important point is frequently lost sight of that the mechanism offered or suggested for handling the freight so often introduces an element of extra handling. Anyone who knows anything about handling material of any kind knows that the mere transportation of the material may be the minor part of the operation. Anybody who knows anything about handling freight in any important city terminal knows that the mere process of transporting that freight from one point to another may be the easy part of the game.

In any switching or transfer operation there are numerous movements, sometimes lost sight of, which may involve more expense than transporting the cars between points. Our investigation showed that this was true in handling freight mechanically in many cases.

I wish to be understood as not objecting to any particular method of handling, and I must be understood as saying that for certain purposes, mechanical handling of many kinds is well devised and economical, but it seems to me that mechanical handling must be adopted with caution, it must be adjusted to the needs. We constantly found in our investigation, more or less superficial though it necessarily was, the disregard of the subsidiary elements of the process, if I may so term them. We found chutes, for instance, installed to handle freight between different levels of a freight house, put in at considerable expense, and absolutely unused. Why? The freight going through the chute was loaded on a truck, it was then unloaded onto the chute. When it reached the lower level it was again loaded on the truck. Now, study shows that the operation of loading freight onto a truck is one of the expensive elements in connection with the process. If you double that part of the process you immediately have increased cost unnecessarily and have in a way cast suspicion on the method. The fact has been proved in a number of cases. I have in mind a transfer station on the Pennsylvania Railroad. We will admit that the Pennsylvania road's methods are good. We must admire the organization that is in effect on that road. They don't very often do things by guess, and generally investigate matters thoroughly. I found that at one transfer station the process had been to load freight onto trucks and then pile it on a platform, sorting it out there in order to get full truck loads, and then to pass it along to the car. But an extra handling was involved; they discovered that this extra handling was needlessly expensive and it was eliminated. Now, in my view, that is the process which must be carried out. If mechanical handling is to be a success, the means and methods must be very carefully adjusted to the needs.

The President:—Mr. F. L. Stuart, will you kindly give the Committee the benefit of your experience?

Mr. Francis Lee Stuart (Baltimore & Ohio):—Mr. Chairman, I agree substantially with Mr. Lee. There are but few general cases in which we have found mechanical handling to be an advantage. It is, usually, useful only in specific cases. No doubt, as the art improves, mechanical handling will become more useful.

There is one suggestion I would like to make. The plans for the yard are quite complete, but we must go further than that; we want plans for a general yard organization. While it is true that one railroad may require a certain kind of organization and another a different kind, still I think the Committee can outline an organization that will be efficient and practical under ordinary circumstances for yard work, and one that can be molded to suit a great many conditions.

There is another suggestion that occurs to me: We should be able, at many points, to change engines, cabooses and crews on one or two side-

tracks, with only lateral tracks to set off on or pick up from and cut out some of the delays which occur in a yard with many tracks. The times are such that we may have to make every "edge" cut, and it is well worth the thought of your Committee to design the simplest kind of a siding possible, with some method of setting off and picking up with a minimum amount of switching and delay and keep the trains moving. Such an arranged yard would also be useful as a collecting and distributing yard for such points as require a single switcher, etc.

Mr. W. B. Scott (Southern Pacific Lines):—I do not believe that I can qualify properly on this subject, although I have had a little experience with it. The point brought out by Mr. Lee seems to be a very pertinent one. We have found that the reloading of trucks practically eats up the saving in expense of the mechanical operation.

The President:—Mr. Coburn, we notice in the report of the Committee on Buildings, page 710, Bulletin 163, that some observation is made respecting the conclusions in the Manual under the head of "Yards." Do you desire to explain at the present time that reference in your report in connection with this Committee's report?

Mr. Maurice Coburn (Vandalia Railroad):—The situation is rather unfortunate, and I think the Buildings Committee owes an apology to the Yards and Terminals Committee. We thought that we knew what they had reported, but we did not. At the last moment, before our report was printed, we found that we were overlapping them, though we had thought, from our correspondence with the chairman of that Committee, that we were not doing so. I hoped to have a chance to confer with Mr. Spencer before he appeared.

We have a report on the design of freight houses. We have discussed in that report the size of the houses, and also some question as to fire protection, which had been discussed in previous reports of the Yards and Terminals Committee. There was also a question as to whether there should be an outside platform or not. As I have thought over the matter since it seems to me that, perhaps, the Yards and Terminals Committee should designate the proper width of the house and its size, and at that point the Buildings Committee should take up the question of design of the building. We have not had any chance to confer with the Yards and Terminals Committee, but since we are the trespasser, we are perfectly willing to meet any recommendations they have on the subject at this time. We had the report printed in this way because we felt that if what we had recommended was a proper part of our report, the Association could let it stand.

Mr. Temple:—In regard to the recommendations which are made in the Buildings Committee report, as to the sizes of inbound and outbound freight houses, I do not think that they differ materially from what is in the Manual under Yards and Terminals. I would suggest, if it is in order, that the two committees get together and submit something that will not conflict, and, if it is not too late this year, then have it inserted in the Manual. I think the matter ought to be stated in the Yards and

Terminals Committee report in a general way, without going too much in detail and have the Buildings Committee treat with the subject more fully.

The President:—The report of the Committee on Buildings will not be considered until to-morrow. It is suggested that these two committees agree on what changes they desire before the report of the Committee on Buildings is brought up. The next subject is "Report on Developments in the Design and Operation of Hump Yards."

Mr. A. Montzheimer (Elgin, Joliet & Eastern):—The sub-committee on design and operation of hump yards considered the question of new construction of hump yards and picked out the Canadian Pacific yard, at Winnipeg, as a typical hump yard of recent construction. They also tabulated a list of the various hump yards in the United States and Canada. The list is shown on page 93. The suggestion recently made by Mr. Stuart, that the question of the operation of hump yards be gone into, was also considered by the Committee. They made up a list of 28 questions with a view of obtaining information as to the different methods of operating hump yards. On account of the large amount of information required we reduced the list of 13 questions, with the idea that at some future time the other information would be obtained. You will note in the report that we have gone into the question of cost per car handling in hump yards, compared with the cost of handling the car in the ordinary flat yard. The information is not altogether satisfactory, because we find in modern hump yards more work is being done in the way of classifying cars than was done in the old flat yards. Trains are made up with cars in station order and in many cases cars are weighed, where formerly they were not weighed. We have also gone into the question as to the amount of business that would warrant the construction of a hump yard; also the question of grades on the hump and the location of the track scales in reference to the hump. We also investigated the necessity of departure yards. Some railroads are using departure yards and some are not. It is thought that taking the possible hundred hump yards that are in the United States and Canada, a great deal of information can be obtained and certain rules laid down as to the best methods for operating hump yards. If the Committee is granted further time on this, we can bring out a larger amount of valuable information in reference to the operation of the hump yards.

Mr. W. L. Trench (Baltimore & Ohio):—I would like to ask if, in the design of the hump on scales, as shown on page 35, consideration was given to selecting grades so that there would be a sufficient separation of cars at the switch of the dead rails, so that the switch could be operated either by hand or by interlocking without withdrawing the cars coming up the grade? On our line the scale people are very insistent that the non-weighers use the dead rails. This requires that the switch be operated each time there is a change from weigher to non-weigher. In the way the hump is designed, there is not only loss of time in withdrawing the column of cars down the approach grade, but there is wear

and tear on the equipment, which would seem unnecessary, and there is loss of steam. I would like to ask whether this was given consideration.

Mr. Montzheimer:—We asked each railroad operating hump yards what grade, if any, they recommended different from that shown in the Manual. On insert sheet, railroad J, page 134, is shown the hump grades recommended by the Baltimore & Ohio Railroad, and these are the grades that they are using at their hump yards. I presume, since Mr. Trench has mentioned it, that this is the grade they recommend to take care of the movement of cars through the dead rails at track scales, thus avoiding slowing up of the cars.

Mr. Trench:—That does not seem to be the case. The switch of the dead rail is reached before the crest of the hump is reached, and it is necessary to stop the train and withdraw it in order to throw the switch. It would probably be necessary to have a separation of cars of at least 20 ft. in order to give an opportunity to throw the switch from an interlocking tower or by hand.

Mr. G. D. Brooke (Baltimore & Ohio):—The accurate weights of cars passing over scales is considered much more important now than it was a few years ago, or rather the question of getting accurate weights. Until recently cars were weighed in motion at considerable speed. Our scale bureau now requires that cars be moving not over four miles an hour. It is very difficult at that speed to obtain a separation of the cars so great that the switch can be operated between them, particularly on existing humps. A great many of the scales were installed after the humps were built, and it was not practicable to revise the grades to such an extent as to obtain that separation. Then, if that separation is obtained, the car is moving too fast before it reaches the scale; so that there seems to be no practical arrangement of grades that will obtain that condition, and it is necessary when changing from the scale rail to the dead rail to withdraw the cut of cars.

Mr. Trench:—I think that this point should at least be given consideration before a standard hump is adopted. I believe it is possible to design a hump which will give the separation and possibly slow down the car at the scales to the required limit. I think that should be gone into; or, it might even be possible to design a scale for use on humps in which the weight could be lifted off the knife edges from the tower or by hand lever and make dead rails unnecessary.

Mr. Montzheimer:—The diagram on insert sheet, page 134, shows the profile of humps of the railroad J. These are the grades recommended by the Baltimore & Ohio and are in actual use at the various yards. I take it that these grades shown on the insert sheet referred to will take care of the conditions that are mentioned.

Mr. C. E. Lindsay (New York Central & Hudson River):—I have nothing to say on the subject of track scales, but I would like to say, in view of the fact that the Committee on Yards and Terminals has made no recommendation for next year's work, that the design of a hump yard is intimately related to the operation of it. It is impossible

to study one without studying the other. We have been studying our yard at West Albany very carefully and have endeavored to increase its capacity by the use of some means of returning the riders to the hump, which we found was one of the greatest sources of delay. We also found it necessary to take into consideration the direction of prevailing wind, the temperature and the operating conditions as to the trains coming into the receiving yard, as to how long they stood before they were humped—all of these things will be, I believe, of value in the further study of this subject. I believe the Committee is working along the right line.

The use of poling cars has also become profitable with us where hump cars are not possible. We have found we can increase the capacity 25 per cent. by the introduction of the poling system without increased cost per car.

The President:—Has anyone any suggestions to offer as to next year's work?

Mr. L. A. Downs (Illinois Central):—In connection with the work on Yards and Terminals, design of hump yards, etc., I believe attention should be paid to the movement of cars. Yards, as we know, retard the movement of cars. Statistics on all the railroads of the United States show that freight cars move less than thirty miles a day. Transportation experts say that on well-organized and well-regulated railroads, when a car is moving that it makes 10 miles per hour, therefore it should make 240 miles miles a day if not retarded. Therefore, there is a loss, as you will understand, of 210 miles in each 24-hour movement of cars. Of course, transportation experts will see that the proper cars are put in trains, at certain terminals, to run to various other terminals without switching. Sometimes the cars are not put in those trains, with the result when they get to the next terminal, they run over a hump or into another yard and are switched again. I think it is a part of the work of this Association to design our yards and terminal facilities, such as coaling and water stations, in such a way that they will increase the movement of cars. I think that one of the greatest losses that the railroads now have is the use of the car. The car is the revenue producer, and, of course, what we get out of the use of the car is our revenue. Therefore, in the designs of the different yards and terminals, just like the workings of the individual hump, the workings of the entire system in the organization of the terminals should come into play.

In other words, if the originating terminal is A, as much as possible all cars for Z should be switched to go in that train and go by these other terminals without this great delay in each 24 hours. Even if the railroads of the United States could increase the mileage of their cars five miles a day, it would be millions of dollars in revenue to the railroads. I think it is the work of this Committee to so design the yards as to figure the movement of a car continuously through the terminals without switching, which will minimize the delay.

The President:—The Committee is dismissed with the thanks of the Association for its faithful work.

DISCUSSION ON ROADWAY.

(For Report, see pp. 383-400.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ROADWAY.

J. R. W. AMBROSE.
GEO. W. ANDREWS.
C. H. BLACKMAN.
W. M. CAMP.
J. L. CAMPBELL.
CHAS. S. CHURCHILL.
W. H. COURTENAY.
W. M. DAWLEY.
CURTIS DOUGHERTY.
H. T. DOUGLAS, JR.
J. B. JENKINS.
P. M. LABACH.
J. R. LEIGHTY.
HUNTER MCDONALD.
JOHN G. SULLIVAN.
ALBERT SWARTZ.
F. E. TURNEAURE.
J. E. WILLOUGHBY.

The President:—The next report will be that of the Committee on Roadway. The report will be presented by Mr. W. M. Dawley, the Chairman of the Committee.

Mr. W. M. Dawley (Erie):—The Roadway Committee had for consideration three subjects, the first being unit pressures allowable for roadbed of different materials, which was assigned to sub-committee A. This Committee is not able to make any definite recommendations as to allowable pressure until a certain amount of information has been determined experimentally. Mr. Ambrose, of the Committee, has conducted some experiments which are described in the report and illustrated by some photographs which may be of interest. If any of the members care to ask him questions he will be glad to answer them.

A Special Committee has been appointed to determine the distribution of live loads and impact on the track, and how it is influenced by the different weights of rail, to consider tie lengths, tie spacing, distribution and variation of the load throughout the ballast, to determine what is necessary for a proper depth of ballast and also the capacity of different classes of soils to support the various loads. This calls for a classification of soils in order that the recommendations of the Committee may be applied with judgment. There is also called for a determination of the mechanics of the problem of supporting a load on a soil plane, without any surcharge, such as placing ballast on a subgrade or embankments on a level plane. After we have obtained this information, we think it will enable us to design a track and superstructure with a definite knowledge of the value and distribution of the forces involved, to get at the proper depth of ballast, of tie spacing, length of ties, etc., with some confidence in the results to be obtained. It may be that our rail is subject to stresses in the present design of track which might be greatly reduced if we knew the value of all the factors entering into the problem. It may also be possible to reduce the cost of maintenance. If the Locating Engineer in selecting new locations knows defi-

nitely what load the soils will carry, he may be able to vary the location of his track, when he finds it necessary; instead of building across unstable soil, a short line, it may be profitable to build a longer line on stable ground. He will be better able to judge, with the information which we are seeking, than he is at the present time. The principal benefit to be derived will be an increase of safety first, followed by a decreased cost of operation and maintenance.

A Special Committee has been appointed and arrangements made to provide a sufficient fund to start the work, and in case the expenditure should run beyond the amount provided the Committee suggests that the various railroads represented in the Association contribute to the fund on a mileage basis or some other basis to be determined by the Board of Direction. We are of opinion that if the matter is put up to the railroads in the proper light, they would be glad to contribute. The amount required of each would be very small. The Committee could hardly be expected to hold itself to the small amount of money which we have in sight. Perhaps Mr. Leighty will give us some information of what might be saved in maintenance cost if we could improve on the character of our track.

Mr. J. R. Leighty (Missouri Pacific):—This is a rather broad question, and I should dislike to start a discussion on such broad lines There is no doubt that greater permanency in the type of track construction would result in considerable saving by the investment, under very heavy traffic conditions, but under ordinary conditions, and for the ordinary traffic that our main lines have to carry, I believe we have about as economically maintained, and as desirable a type track construction as it is possible to get. I have given some thought to the question of greater permanency and have made some tentative figures on a design, using a continuous concrete base, with I-beams imbedded, supporting the rail, which is used only to make a running surface, and under a traffic of about sixty trains per day on one track it would pay as an investment That seems to be about the number of trains at which it would begin to be a good investment. There are so few miles of line with such a traffic, especially in the West, that I did not go into it further. So far ass I am able to see, the general design of track as it now is, is about as economical as we could expect to get for ordinary traffic, under usual climatic and soil conditions, in this country.

Mr. J. R. W. Ambrose (Grand Trunk):—I will be frank to admit that when I was first placed on this sub-committee, I thought, in view of the different classes of roadbed varying from solid rock to muskeg, that this was rather a foolish proposition, but after floundering around a bit trying to perform a few experiments, the subject seemed to broaden out and seemed to have some possibilities.

I finally performed these experiments shown in the report, from which we gather that there is something to be learned from this kind of work The experiments show the effect of static loads only, but we are

endeavoring to devise an apparatus that will register the effect of any moving load, and these experiments are to be made with that view and not for results.

At the present time I have, about half complete, an apparatus which I think will record the effect of all moving loads.

The moment we start to analyze the stresses in the roadbed, the question arises what are the loads delivered to it, their direction, magnitude, etc., which means that a study must be made of the rail, ties and ballast, as to how the loads are distributed through them.

We have concluded that there are no formulae regarding earth pressures that can be applied to this case, and if anything is to be learned regarding this subject, it must be done by experiment.

I understand there is a Special Committee appointed for that work, who will have an adequate appropriation.

I think these experiments should be performed on various classes of roadway and also under different conditions of track and traffic at the same location.

Considering the status of our funds, I do not believe we can do anything further than design an apparatus that will measure the actual stresses in the track.

Prof. F. E. Turneaure (University of Wisconsin):—Mr. Chairman, I have just arrived and have not heard this discussion. I have, however, had a little experience in making experiments with a sub-committee of this Association on stresses in bridges under traffic conditions, and I appreciate to some extent the difficulties that are in the way and that have to be overcome before reliable results can be obtained. I think that the difficulties in measuring stresses in roadway will be more troublesome than in the case of steel structures. For example, in our experiments on steel structures we found that our results were satisfactory until we got down to a span length of 25 ft. When you come down to rail and ballast, you get down to a shorter span than that. If the Committee is able, within a year or two, to devise an apparatus to do that work, they will accomplish a great deal. If an apparatus can be devised that will give satisfactory results, a great deal can be learned unquestionably from such experiments. The wave motion that proceeds from the rail and the ties down to the roadbed is something that must finally be determined. That will be difficult to accomplish.

Mr. P. M. LaBach (Rock Island Lines):—The diagrams given in the report of the Committee on Roadway show graphically what was found in these various tests. The diagram on page 388 also shows what we would expect to find by a mathematical analysis. The stresses in track, when we come to investigate them theoretically and practically, must be worked out by the utilization of elastic factors. The rail is subjected to both positive and negative bending moments. These are influenced by the spans of the locomotive wheels as well as the tie spacing. The bending of the rail downwards will load the tie. The amount of this bending will depend on the elasticity of the rail. In other words

the load on the tie would be different with different weights of rail
the wheel load remains constant. The maximum load on the tie w
when the wheel is immediately over it. The form which we expec
tie to take will be such as is found on page 388. The depression
tie will be at a maximum at a point underneath the rail base. The
of the tie will be in tension on the bottom at this point and in
pression on the top. In the middle of the tie the reverse is true, t
fibres are in tension and the bottom ones in compression. The
pressive stresses in the ballast regarded as a partially elastic sul
will be proportioned to the depression. This depression being g
immediately under the rail the ballast has a greater load to carr
at any other point. Their maximum load is distributed throu
ballast to the roadbed. The manner in which it is distributed d
upon the elastic working of the ballast. If the elastic limit is
ceeded we get good results with a given thickness of ballast. Wi
elastic ballast or a greater load the results will not be the same.

When you try to figure out the stresses in either the rail or
mathematical formulae are rather long and complicated but th
been done and can be done again. The use of measuring instr
on ties in track has been tried and the results tabulated. By the
formulae which provide for maxima and minima the stresses
working conditions may be found.

It is interesting to know that along about 1867 or 1868 a G
engineer named Baron von Weber went into this subject and after
tests wrote a book upon it. He has been followed by others, nota
Dr. Zimmermann in Germany, Mr. Ast in Austria, Mr. Wasintyn
Russia and Messrs. Cuenot and Schlussel in France. The records
tests made by these gentlemen have been published and a numb
general works written on the mathematical phases also. All the
gineers regard the track superstructure as elastic and derive their
with that conception of the subject.

Mr. W. M. Camp (Railway Review):—I believe the subject
discussion is unit pressure allowable on roadbed of different ma
and the design of track with reference thereto. Of course, we
stand that the unit pressure resistance of soil has an intimate r
with the elasticity of track supported on that soil. The railroad
of the United States are almost universally of a common design,
it might seem trite to suggest that there are not any questions reg
that design to be considered. Finely worked-out data or formul
allowable pressures may prove to be of but little use, but there are
applications of knowledge of relative supporting power of soils
can be made in practice, and which, for that matter, always have
recognized.

The materials that have been used for ballast on American rai
have been largely of broken stone, gravel, sand and common
Those four kinds cover nearly the entire mileage of track that i
lasted at all. Broken rock has a better sustaining power than g

gravel has a better sustaining power than sand, and sand has a better sustaining power than common earth. One will find that, for a long time back, where earth ballast was commonly used, particularly in the South and Southwest, 9-ft. ties were frequently standard, while in the North, where the ballast was usually of better quality, a tie 8 ft. long was the standard, and is still, to a large extent. Here was a practical recognition of the difference in supporting power of different kinds of ballast, and such knowledge affected the design of the track to the extent of lengthening out the tie where it was used on the poorer ballast.

I was present in a railroad convention a few years ago when the inquiry came up as to how the 8-ft. tie came to be selected as the standard, and I believe it was pretty well agreed that the lumbermen settled that question. The 16-ft. saw log was a very common length of cut for timber. At the mills they cut lumber of that length in two and made two ties of it. From the fact that 8 ft. was a convenient length to make a tie, that became the standard length; but during the past ten years engineers have been getting away from that rule of expediency applied to the length of the tie, and quite commonly 8½ ft. has been adopted as the standard length: A good many think that is the economical length of tie. Given a tie 7 in. thick, as you lengthen it out you increase the tendency for the tie to spring, and when you get a tie springy the sustaining power of the tie is not satisfactory. As we lengthen the tie we must increase the depth. The length of tie is thus a question in the design of track which is a very practical one, and one which is very readily solved.

The motive power department has been increasing the weight of locomotives and rolling stock without consulting or even regarding the engineering department. The engineers have simply had put up to them the question as to what they were going to do to hold up the increased weight of traffic, and that should be one line of investigation by this Committee. The question of increasing the bearing surface of the track, is, of course equivalent to decreasing the pressure on unit surface of roadbed. The more bearing surface there is to the track structure the smaller the pressure on the unit of roadbed surface. In swamps, muskegs and sink holes, as we call them, there is material which has very little sustaining power. Railroads have been laid over ground which had not sustaining power enough to hold up a horse or even a human being. In such cases it became necessary to throw in brush or logs and thus widen out the roadbed, in order to sustain the track. There are all degrees of softness in such roadbed. In one instance, on one of the Canadian roads, use is made of 12-ft. ties, on some of the muskegs, in order to increase the bearing surface of the track. I think it is along such lines of investigation, rather than in the working out of precise formulas that the best work of the Committee can be done, to see in what practical ways this matter of increasing the bearing surface of the track on the soils that we have to deal with.

We have to take the soils as we find them. We cannot tr
gravel long distance, from one place to another, to make a r
we have to be satisfied if we can get enough of it for ballast.
as the roadbed is concerned we have got to take the natural sur
the earth. I heard some discussion in an early annual meeting
Association when the question came up as to whether the motive
department should not be requested to stop increasing the size
locomotives, and it was asked whether or not they had not alre
ceeded the ability of the soil to sustain the loads. I recall t
member stated that he had assumed the ultimate bearing power
soil to be something like 55,000 pounds to an axle. Another
Mr. Lum of the Southern Railway, I think it was, who said: "No
how we theorize about this question or what we find to be t
allowable pressure, old mother earth has got to carry the railro

Mr. Leighty:—In line with the remarks just made by Mr
we have found in a great many cases where our track is unball
mud track, that after a certain amount of rainfall, the bottom
drops out. We have apparently no sustaining power in the roadbe
is practically impassable. Under these conditions we have in eve
so far as I can recollect, made the track passable and reasonab
by filling in ties, that is to say, by putting ties in between those
in the track. That accomplishes the same thing Mr. Camp speak
without making the tie a longer beam, and, therefore, making i
sary to make it a deeper beam. I think that track maintenan
territory where the rainfall is great enough to make considerable
or ballasting material so expensive that it is almost prohibitive,
natural soil is of such a nature that a little rainfall makes it ba
the thickening of the ties, putting in more ties to each rail leng
do a great deal toward lessening the cost of maintenance. In
treme case, where the track is practically impassable under o
conditions, it can be made passable and reasonably good by pu
an almost solid floor of ties. If that can be done, in such an
case, there will be some locations where track can be improved
will get a greater economy of maintenance with very little bal
adding more ties.

We have made an effort in the last few years to distribute t
load over a greater area of roadbed by making the rail deeper or
Some roads have offset that by lessening the number of ties un
rail length. I could never understand the philosophy of that ki
move. We spend additional money for rails to accomplish a cer
sult, and then reduce our expenses by reducing the number of t
when we get through we are just where we started.

Mr. Albert Swartz (Toledo Railways):—I do not see why th
mittee should not go through with the investigation to determi
bearing power the different soils have. It requires some study
termine that capacity of the soil, and I think the Committee sho
ceed with its investigation.

Mr. Camp:—I do not like to be misunderstood. It is not my idea to suggest that the Committee should not go ahead with its investigation. I think they should continue on the lines laid down. I tried to make clear my opinion that there are certain limitations in the designing of track to meet various conditions of soil, unless we get some type of track radically different from what we have now. From the well known fact that the sustaining power of soils may vary greatly in a single mile of track, and that it does so vary on a large mileage of many of our railroads, I will venture the prediction that track design, however much it may be improved, will, for the same railroad, continue to be built pretty much as at present, namely one standard design for the whole road, with, possibly, special construction for particularly soft places, as through swamps and bogs. Longer ties and closer spacing of ties can increase the bearing surface of the track, and deeper and stiffer rails can distribute loads over more roadbed surface. The character of the ballast also has a relation to distribution of the load, as previously stated. With track of present type (and we know of none better) the possibilities in these directions are the limitations that I wish to point out.

Mr. John G. Sullivan (Canadian Pacific):—I was on the Roadway Committee at one time, and I opposed the making of these experiments for the reason that if you make them under all conditions you will find that you will get earth that will bear from 10 to 15 lbs. per sq. in., including in the word earth solid rock, up to earth which will bear a locomotive on one square foot, and I cannot see that the results which you will get will be of any practical value. We had some earth on our track near Winnipeg on which you could run locomotives without rails in the dry season. In a wet season you could not run a baby carriage over the same ground. Therefore, experiments in that particular case would show very different results according to the day on which the experiments were made. We laid that track when there was frost in the ground—we could not have laid it in any other time without putting in brush or cross logging. We managed to get some ballast on it, but before we did that the mud came to the top of the rails, dried out slightly, evidently it was somewhat harder than the material under the tie, and at some places in that track we put two or three feet of ballast, and in three or four months these ribs of clay would come up through the ballast.

Of course, you will say that was not the way to do it, the way to have done it was to round off grade, as shown in standard plans, secure good drainage and good ballast on them. If anyone can tell me how you can put ballast on a track which you cannot drive a team over, and get the sub-grade in shape for them to do it at any reasonable expense, we would welcome the information. I do not know how to do it. You must lay the track and put your ballast on it. We overcome the difficulty by putting on enough ballast to overcome the load.

I can see only one reason for these experiments. There are many tracks in the West that are suffering for lack of ballas maintenance would be much less if the tracks were properly b If the Committee can bring in a report which will convince the Managers that they should really put on ballast enough to h track properly, it may do some good. As a means of education t neers, it will be simply useless.

So far as the ties are concerned, the 12-ft. and 16-ft. ties— some 12-ft. ties—they are not to carry the load, however, but to the load. The 8-ft. tie will break under the rail now rather tha in the center. The purpose of using the 12-ft. tie is to steady t and prevent creeping. We put in the longer ties, because th anchorage you have for the rails the less trouble you will hav creeping track. We practically abandoned the 12-ft. tie in regula but we use them now to keep the track rigid and level, we pu in at soft places or joints, or other points at which we anchor th

-We had some discussion recently in the Canadian Society o Engineers about ties, and I went into the matter, and figured the a beam loaded uniformly, turning the track upside down, if yo It is true you should not tamp the tie in the center as hard as y at the ends, I think you will find you should not go over 8.5 ft. a uniform loading. If you make it over 8.5 ft. you will have th breaking under the rail.

We had an Engineer make some tests on the eastern part road, and some of those tests were rather unique and gave sur results. They were made for testing the strains on the track of di rolling stock. It was rather surprising to find that every wheel locomotive exerted a very great outward pressure. A great many been thinking, and they seem to have practical reasons for bel that in the case of an engine running slow the flanges of the drivers will not touch the outside rail. I do not believe in any pla the lateral stress in the track exceed 20 or 22 per cent. of the l the wheel. Therefore, you get a stress on the track without hav flange strike the head of the rail, but the most surprising thing we —and these were the results of probably 600 or 800 tests—wa some freight cars exerted a greater pressure on 6 and 8-degree than our locomotives. If the Committee, instead of endeavoring some things that are immeasureable, will test the strain of the stock on the track for lateral movements, I think they will formation which will be of more benefit to the Association.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Lou came in after the discussion had gone too far for me to know what the matter before the meeting is. I presume it is on the q of the Committee's request for privilege of making experiments depth of ballast. I am not now able to express an opinion on the r they propose, but certainly sympathize in their desire to make st periments. While Mr. Sullivan may have a condition of affairs th

be exceptional, in regard to the character of material he has described, it seems to me that some of that material ought to have piles in it. I do not believe it would be good practice to let that stuff dry out, and then get wet again. It should be piled to begin with.

There are plenty of roadbeds in the United States, and I am satisfied there are plenty of them in Canada, where it would be practicable to find out what amount of ballast would be needed on the average roadbed. I believe the tendency of to-day is to keep the track about 25 per cent. behind the equipment. I think we ought to get the track up to the equipment, but I do not believe we can do it unless we can show our managements that more ballast is needed, and I am heartily in favor of some experiments to that end.

Mr. Geo. W. Andrews (Baltimore & Ohio):—Mr. Sullivan's remarks reminded me of the old story of the shipwrecked Irishman. He was picked up and brought on a vessel in the last stage of exhaustion. When he was aroused he said: "Have you a government here?" The answer was that they had. He said, "Then I am agin it."

I believe this Committee should continue investigations along the line on which they have been working. Mr. Camp has outlined a method that the Committee could give very close attention to. We know that what Mr. Camp has said is a fact. We also know that the money put at our disposal for ties and ballast is rather limited. We cannot put concrete under ties if we do not have money enough to buy sand. I can recall that some years ago on the road I have been fortunate enough to be connected with for a good many years, that we installed a system of track tanks. The Division Engineer went over the territory shortly after the tanks were installed, and called the attention of the section foreman to the fact that they must exercise a great deal of care not to allow pieces of ballast to rest on top of the ties as the scoop on the tender was sufficiently low to strike the ballast, damage the scoop and prevent it from taking water. One Irishman said, "No danger, no danger; we do not get money enough to put the ballast under the ties without leaving it on top." That is the condition most of us are in. This Association cannot take the stand where they will say we have reached perfection and will stop.

Mr. J. L. Campbell (El Paso & Southwestern):—I think the last speaker has come pretty close to the heart of this proposition. I take no exception to these experiments if they result in showing the management that more money is needed for the track. I do not believe that the trouble is primarily lack of knowledge as to what should be done. As a rule Engineers have definite ideas as to what should and could be done within economical limits if they could get the money. It resolves itself into a question of how shall we get the money to improve the track and to what extent would we be justified in spending money on the track to increase its general efficiency. I anticipate that in a general way our tracks are about what they ought to be and I believe we are building and maintaining about as good tracks as the traffic justifies. Whatever

our knowledge may be of what might or should be done later
business increases, I believe we are doing about all that we sho
the present time. I believe the managements of our railways
that and that that is one of the reasons we are not getting mo
to improve our track, because the question of increased permane
be considered in connection with justifiable expenditure.

I think the information that the Committee could secure
all right bearing in mind what has been said about the instabili
soil and its carrying capacity under different conditions. Assu
the diagrams presented by the Committee are correct and that t
the stresses as they act on the roadbed and that it is desirab
prove the stability of the track, has the Committee any definit
how the information so secured would be applied? How
modify the design and construction of track in case increa
manency of the latter was ordered?

Mr. Ambrose:—At one time I acted with Mr. Sullivan on
committee and if the work of this Committee is to be limited to s
allowable unit pressure on roadbeds, I would be inclined to a
him, but the subject is broader than that. The moment we co
pressure in the roadbed we find that the rails, the spacing of ties,
and kinds of ballast, all have their effect on the roadbed and
segregate one from the other in this study. We all know the
dition is a uniform loading on the sub-grade. How to attain
dition and when it is, or is not necessary, is the problem c
this sub-committee. I believe, therefore, that we should wo
with the other committees and take the whole problem u
sideration.

The President:—The Special Committee on Stresses in
pects to take up the study of the entire subject of stresses in tr
ties, ballast and roadbed, so that no one feature of the proble
studied to the detriment of the other.

Mr. Camp:—I am in favor of getting all the informatio
on the allowable pressures on earth, and I cannot see any ha
Association or anyone else making tests to discover what
Scientific data on this subject will harm no one. Many membe
Association started out with academic information in the first
they have found by experience what use could be made of
I have no expectation that new data or information along
we are discussing will revolutionize track construction, yet I
more knowledge we can get of roadbed conditions the broad
our understanding of what we are doing.

There is another possible line of utility in this proposed in
which has not been mentioned, and that is this: If the Com
ascertain what are the allowable unit pressures on soils as they
about the country; then if the Association has the courage to
can say to the managements of the railroads that the time
when the motive power departments should stop increasing t

of the rolling stock. I read a quoted remark of a member of the Interstate Commerce Commission, not long ago, in which he said that if the government had to step in and regulate the construction of railroad tracks, it might, about the first thing, have to decide whether the allowable loads that are carried over the tracks had not already reached a safe limit. If the Committee can get some data on this subject that will appeal to railroad managements, in a manner to draw attention to this ever increasing weight of rolling stock and the economical effect thereof, I think it would be a very good plan to have in view.

Mr. C. H. Blackman (Louisville & Nashville):—There has been a great deal of criticism of the Committee in regard to its measuring the amount of pressure on the soil, but if the Committee can determine how the pressure from the axle load is distributed and transmitted to the ties and through the ties to the ballast under the ties, it will be of wonderful assistance to such of us as have to design structures to go underneath the track.

The President:—If there is no further discussion on this phase of the subject, we will go to that part of the report which treats of tunnel construction and ventilation.

Mr. J. E. Willoughby (Atlantic Coast Line):—The Committee has considered this subject for several years and has tabulated conclusions which appear to be representative for a number of tunnels not more than a mile in length. We recommend that the conclusions which appear on page 399 under the heading "Tunnel Construction" and "Tunnel Ventilation" be adopted.

Mr. Sullivan:—I think conclusion 1 will have to be modified, depending on the material through which the tunnel is driven. If it is a case of solid rock, and the railway did not have traffic enough to justify the running of the tunnel, it would be more economical driving to take out, say, three benches, shooting the three benches at the same time, and doing as much mucking as possible with the steam shovel.

Mr. Willoughby:—The Committee is of the opinion that as tunnels are ordinarily constructed when the time limit is not of great value, the unit price of the removal of the tunnel section will be less if the heading is driven entirely through and then the bench be removed afterwards.

The Committee believes, however, that when material does not require support, there are often advantages both in time of construction and in less unit cost in driving a bottom heading first and removing the material by an air or electric shovel; and makes this suggestion further on in the conclusions.

Mr. J. B. Jenkins (Baltimore & Ohio):—With regard to conclusion 5, which provides that opposing grades should never meet between the portals of a tunnel, so as to put a summit in the tunnel, I would say that it is sometimes necessary for the purpose of drainage to have the opposing grades meet between the portals.

Mr. Willoughby:—The Committee believes in view of its previous investigations, that a tunnel should never be built level, but built at

least on a 0.2 per cent. grade, and it is the opinion of the Committee that it is better to take the drainage through the entire length of the tunnel, than to put a summit in the tunnel, with two opposing grades.

Mr. Jenkins:—Sometimes the two portals of the tunnel are necessarily of the same elevation, in which case I think it is better to put a summit in the tunnel than to have a level grade.

Mr. Willoughby:—The Committee believes that in the construction of a tunnel such control can be had of the grades on either side as not to require that kind of construction.

Mr. Jenkins:—I have had one case where it was impossible to make enough difference in elevation between the two ends of the tunnel to provide drainage from one end to the other. I think that paragraph should be qualified.

Mr. Chas. S. Churchill (Norfolk & Western):—I agree with Mr. Jenkins. We should not insert anything in our conclusion so absolute as "never," that has been the policy of the Association. The words "preferably not" would be better. There are conditions conceivable in any location where it is desirable to have the two ends of the tunnel practically of the same level, and there is certainly nothing wrong then in securing drainage in the method suggested by Mr. Jenkins. Whether that is a fact or not, the word "never" is not a good word to use in a conclusion of this kind.

Mr. E. B. Temple (Pennsylvania Railroad):—What effect will a pronounced summit in the grade have on the ventilation?

Mr. Churchill:—There is very little difficulty in the ventilation one way or the other, provided there is not too large a break in the grades. When air is started through a tunnel with sufficient force behind it, it will go through. It makes no difference whether there is a broken grade in it or not. Grades do not enter into the calculation. All that enters into the matter of moving air is the resistance of the walls of a tunnel combined with the cross-section and length of it.

Mr. Campbell:—I do not think "never" is a good word to use. Still it is important that opposing grades do not meet within the tunnel. I think it would be better to say, "where practicable, opposing grades should not meet within the portals of the tunnel."

Mr. Churchill:—Take the case of a tunnel passing under a river, the New York Terminals, for example. There we have tunnels of about the same level at both ends, and as we know there is a very strong dip in going under the river, and a summit under New York. There is no trouble in ventilating those tunnels. I mention this to show it is impracticable to always arrange tunnels so that there shall be no broken grade therein.

Mr. Willoughby:—The reading of the Committee report is "summit."

Mr. Churchill:—The same thing.

The President:—The Committee will accept the words "preferably not."

Mr. W. H. Courtenay (Louisville & Nashville):—I agree with the Committee that where it is possible to do it there shall be no summit in the tunnel. The summit is an unmitigated nuisance. On the road with which I am connected we have a tunnel which has a summit in it. We have other tunnels which have no summit, the same grade all the way through. The longest tunnel we have is about 4,600 ft., and there is no trouble at all about bad air, or any other conditions influencing the train movement. I have stood on the rear end of the passenger train going up grade in that tunnel without suffering discomfort. We have another tunnel about 3,300 ft. long which has a summit in it, put there for the purpose of dividing the drainage. It was a mistake. The tunnel is wet, the drivers sometimes slip, and it is not an infrequent occurrence that the men on the engines suffer on account of bad air. In nearly all cases, for ordinary tunnels, without reference to such tunnels as those of the New York Terminal of the Pennsylvania Railroad, it is entirely practicable to so adjust the grades that there will be no summit in the tunnel. I entirely concur with the Committee that it is better to pass water entirely through the tunnel from one end to the other, than to have a summit in the tunnel which catches the smoke and holds it there. It has been proven that a straight roof for a tunnel is of very great assistance in clearing it. We have stopped up shafts that were used for construction purposes merely to get better draft. With the long tunnels built in recent years there has been no trouble in getting rid of the gas, but in old tunnels, where they had shafts and where there was a summit in the tunnel, there has been great trouble.

Mr. Curtis Dougherty (Queen & Crescent):—Mr. Courtenay has said about all I had in mind to say. I am in similar territory and our situation is quite the same. We have tunnels on straight grade in which, as stated by Mr. Courtenay, the ventilating conditions are better than in shorter tunnels where a summit is provided in the tunnel. I agree with him that it would be better to take care of the water in a tunnel with a uniform grade than to be up against a tunnel with a summit in the middle, providing adequate arrangements are made to take care of the water.

Mr. W. B. Storey (Santa Fe):—The position taken by Mr. Churchill seems to be proper. I know of tunnels that have summits, and are over a mile long, in which the ventilation does not give trouble. Mr. Jenkins is right, however, in many cases. It seems, therefore, if the language of the conclusion remains as now accepted by the Committee, it is along proper lines to secure the best practice, that is, not to have the grades meet, but, under certain circumstances, they may be allowed to meet. The language, as it now stands, covers that point.

Mr. H. T. Douglas, Jr. (Chicago & Alton):—A further objection to a break in the grades in a tunnel, other than ventilation, which has been discussed, would be the probability of drawbars being pulled out, causing break-in-twos and probably serious derailments, and assuredly a derail-

ment in a tunnel introduces conditions which are probably more disastrous than at any other point on the road.

The President:—We should consider the next subject before taking final action on tunnel construction. Let us proceed to tunnel ventilation, page 399. General discussion is now in order. The Committee recommends that these conclusions be printed in the Manual. The question is on the adoption of the recommendation of the Committee, that the conclusions on page 399, under Tunnel Construction and Tunnel Ventilation, subject to the modification of Rule 5, be approved and published in the Manual. The Committee desires Rule (b), under Tunnel Ventilation to read, "To blow a current of air against the direction of the tonnage, train," etc., the word "tonnage" being introduced before train.

(The conclusions were then adopted.)

The President:—The next point is, what work does the convention desire to outline for this Committee for next year? On page 400 the Committee makes a recommendation which will be considered. Have you any further suggestions? The Chair would suggest that in view of the remeasurement of the grading of all railroads, that this Committee on Roadway has an important study which it might be well to take up during the coming year. The Committee is excused with the thanks of the convention.

Prof. C. C. Williams (University of Kansas—by letter):—The report of the Committee on Roadway sets forth many matters of interest, for it is only through the consideration of such data as are presented therein that track as a structure can be consistently designed. That is, unless some knowledge is first had of the character and distribution of the loads and stresses occurring in a roadway, the proper arrangement and proportioning of strength and rigidity in the rails, rail fastenings, ties and ballast are impossible, for random design rarely produces a well-proportioned structure. Although it is doubtless true that these stresses can never be determined with a great degree of precision, yet it is equally true that more information than is available at present is extremely desirable.

A few weeks ago, the writer's attention was called to a pile of perhaps three dozen cracked and broken angle bars at the side of a railroad. Walking along the track he found, in a stretch a trifle over half a mile long, twenty-one joints at which either one or two angle bars were broken. However, the next half-mile contained only two joints where cracked angle bars were discovered. The foreman in charge of the section insisted that the large breakage was due to inferior material. By watching the behavior of the track during the passage of trains it became evident that the breakage was caused by low joints and uneven bearing of the ties on the ballast. The fractures were typical angle bar cracks from the top downward, and were caused, in part at least, by the bending moment occurring when the joint was between two trucks or immediately in front of the locomotive. The greatest upward deflection occurred when the joint was midway between two trucks of a passenger coach. Besides the bending moment, there was, of course, a heavy shear-

ing stress in the section every time a wheel passed from one rail to another. The cracked angle bars which had been removed from the track were not bent in the vertical plane, and hence must have failed by fatigue. The fracture, moreover, very much resembled the fatigue fracture of steel obtained in the laboratory. The ballast was slag and not well tamped under the ties. A portion of the bad half-mile was on a slight embankment and a portion in excavation. The rail was 85-lb. A.S.C.E. section.

It would seem that such a condition of affairs might be remedied, at least, if not entirely obviated, by a proper adjustment of the component parts of the roadway, based upon a knowledge of the stresses existing. In determining these stresses, the experiments performed by Mr. Ambrose and described in the Committee report are of much interest. The electrical apparatus used was similar to a device used by the writer for studying pressures in a grain bin, a brief description of which may be of value.

This instrument utilized the same principle which Mr. Ambrose applied, but in a slightly different manner, namely, that carbon plates were used instead of carbon dust. Sixteen carbon plates, 3 in. by 3 in. by 1/16-in., were placed between two electrodes, consisting of steel plates three inches square. These were inserted in a box with a movable lid against which the pressure operated. The amount of current passing through the series of carbon plates varied with the pressure, not as the pressure, however, consequently the instrument had to be calibrated with known weights in order to secure numerical results. Daniell's cells were used to furnish the current owing to the fact that they furnish a constant voltage; since the metal deposited in their operation is copper instead of hydrogen, there is no increase in internal resistance, which condition results in freedom from polarization and a constant voltage.

This sort of a pressure gage is well adapted to the measurement of pressures like those between ballast and roadbed because it involves very little movement (0.01 in.), and it records the release of pressure as well as the application of pressure.

A complete study of the distribution of pressures and stresses may lead to some improvement in the design of track which would obviate the unsatisfactory conditions described first above. Perhaps a special design for the ballast and ties under a joint made with particular attention to the needs of a joint in this respect might improve the matter. At any rate, such investigations will surely be fruitful of useful results.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 401-406.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

GEO. W. ANDREWS.	E. R. LEWIS.
J. A. ATWOOD.	C. E. LINDSAY.
F. J. BACHELDER.	C. A. MORSE.
W. M. CAMP.	J. C. NELSON.
J. L. CAMPBELL.	C. H. STEIN.
A. W. CARPENTER.	JOHN G. SULLIVAN.
CHAS. S. CHURCHILL.	S. N. WILLIAMS.

The President:—The report of the Committee on Wooden Bridges Structures will be presented by the Chairman, Mr. A. J. Himes.

Mr. E. A. Frink (Seaboard Air Line):—Your Committee has made some progress on the consideration of subject 1, relating to the determination of the strength of sheet piling, but has not yet been able to formulate any conclusions. Referring to subject 2, on the use of guard rails for wooden bridges and trestles, the completion of that report consisted practically in the reconsideration of the conclusion brought in by the Committee last year, which was not acceptable to the convention. We have reconsidered that, have gotten some more information on it, and have formulated and present a conclusion in line with what we find. In addition to that, we find, on reading the supplement to the Manual published last year, that conclusion 2, as given in the Manual, is wrong, in that it presupposes the universal use of guard rails, which was not what the convention intended; so we have brought in our first conclusion, that we amend conclusion 2 as adopted at our last annual meeting to read as follows:

"(1) Amend conclusion 2, as adopted at the last annual meeting, to read as follows:

"It is recommended as good practice, in the installation of guard rails, to extend them beyond the ends of the bridges for such distance as is required by local conditions, but that this distance, in any case, be not less than 50 ft.; that guard rails be fully spiked to every tie, and spliced at every joint; that the guard rails be some form of metal section, and that the ends be beveled, bent down, or otherwise protected against direct impact with moving parts of equipment."

The change in the first part of that is to eliminate the provision that guard rails must be used. The addition of the last sentence is to provide for some suggestions made at the last convention. I move the adoption of conclusion 1 as presented.

Mr. C. H. Stein (Central Railroad of New Jersey):—Should not the last line read, "Direct impact with parts of moving equipment," instead of "moving parts of equipment"?

The President:—The Committee accept that suggestion.

(Conclusion 1 was adopted as amended.)

Mr. Frink:—I move the adoption of the conclusion, on page 403, which reads as follows:

"(2) It is recommended as good practice to use inner guard rails on all open-floor and on the outside tracks of all solid-floor bridges and similar structures longer than 20 ft. in main-line tracks, and on similar bridges and structures in branch-line tracks on which the speed of trains is 20 miles per hour or more."

Mr. J. L. Campbell (El Paso & Southwestern):—In this second conclusion the words "inner guard rail" are used. It seems to me that if we are referring to the same thing, we should have the wording the same in both conclusions. It is quite possible that the word "guard rail" might be taken to mean an outside guard rail unless the definition in the Manual was consulted. My preference would be to have the word "inner" in both conclusions.

The President:—The Committee accepts that suggestion, and will insert the word "inner" preceding "guard."

Mr. A. W. Carpenter (New York Central & Hudson River):—I would like to ask the Committee the reason for recommending the use of the inner guard rails only on the outside tracks of solid-floor bridges.

Mr. Frink:—The Committee considered that the definition of solid-floor bridge would mean that the solid floor was one level floor surface.

Mr. J. A. Atwood (Pittsburgh & Lake Erie):—It seems to me there might be some doubt as to the advisability of that conclusion being accepted by this convention. While, of course, it is not binding on the roads, at the same time it is a strong recommendation that inside guard rails be used on all trestle bridges over 25 ft. The railroads in the South and West have so much timber work that it would be a considerable burden. This conclusion might be taken to mean that we are making this as a strong recommendation.

Mr. Campbell:—We have pile bridges with solid floors which we consider fairly permanent structures. Some of them are considerably more than 20 ft. long. We also have concrete bridges with solid floors, some of which are more than 100 ft. long. We have no intention of putting guard rails on such bridges, as we do not consider it necessary.

Mr. W. M. Camp (Railway Review):—I would like to ask the Committee what the length of bridge has to do with this question. There might be as bad a pile-up if a car went off on the side of a culvert where the opening was 10 ft. wide as there would in crossing a stream 100 ft. wide.

Mr. E. R. Lewis (Duluth, South Shore & Atlantic):—I would like to ask the Committee what the twenty-miles-an-hour has to do with it. Inasmuch as the Committee has given this matter a great deal of study,

I would like to know why they stipulate and how they arrive a minima of the 20-ft. bridge and speed of twenty miles an hour?

Mr. Frink:—We realize that there should be some disti made between main-line structures and rather unimportant branc structures. We tried to find some way to measure that differenc the requirement of twenty-miles speed was the best way that we measure it.

Mr. C. E. Lindsay (New York Central & Hudson River):— to oppose the recommendation. While it is true that this is a Com on Wooden Bridges and Trestles, whatever we adopt here as a def or as to location, will naturally extend to the use of similar devic more permanent structures. We have this anomalous condition i State of New York. A good many years ago, when wooden b were in use, a law was passed requiring the erection of a large w post at each end of the bridge on either side of the track; the id ing that a derailed car would first come in contact with that po fore it could damage the structure. That law was modified to in the inner guard rail, and in addition to that there was a p included in another law, so that the railroad should be punished did not have these appliances. Subsequently the original law wa pealed, but the penalty still remains on the statute books and we still put up posts or put in inner guard rails or get a special disp tion. Whatever we do with this recommendation will naturally e by the act of this Association or someone who takes his cue from this Association does, to structures where the guard rail will not any service whatever. I am not opposed to the use of the inner rail where it will minimize accidents, but there are places where i not serve that purpose.

Mr. F. J. Bachelder (Baltimore & Ohio):—I would like to ca tention to the fact that Mr. Lindsay's argument is a very importan son for not abandoning this particular clause. There is no doub we are up against the question every day of regulations being ma different legislative bodies as to what railroads shall do, how they build their structures and run their roads. Why lag behind and different legislatures to tell you what to do? This question was thoro discussed in Committee and some definite measurements or conclu were arrived at so that they could be used for that purpose; so that the legislatures proceed to tell you how to protect your bridges would not start in with some wild scheme that is absolutely impracti We agree that there is no question that there are locations where guard rails are not needed. The question of how long a bridge t them on was thoroughly discussed. First, we talked of 30 ft. After it was decided to bring it down to 20 ft. The question of what b lines not to include, what was the basis to arrive at a just division discussed, and we decided that probably the speed of trains operat branch lines would be as good a way as any. I should dislike to se body refuse to make some recommendation upon this subject, for I

sider it important. In some states the question is being considered now as to passing regulative legislation on this subject. We should lead in this and not lag behind.

Prof. S. N. Williams (Cornell College):—I trust, gentlemen, that a word in behalf of the general public may not be considered out of place at this time. I wish to express myself as heartily in favor of the recommendation of the Committee. We are interested in all matters which affect the safety of the traveling public, and as railway men we are interested in that which affects the safety of railway property. Many railways are paying a great deal of attention at the present time to the subject of "Safety First," delivering lectures to the trainmen, and perhaps to the general public. It is noted that the general public has been trespassing on the railway companies to such an extent that in my opinion it ought to be prohibited from walking on railway tracks, or on the right-of-way. On the other side, whenever I have traveled on a railway where there were guard rails at the ends of bridges, running all the way across, I felt good, because I said: "This railway has the safety of its passengers in mind, and is doing all that it can to protect the interests of the traveling public as well as of their own train." I am heartily in favor of everything which tends to promote economy and the avoidance of unnecessary expense on the part of railways or the general public or individuals, but I would urge you as railway men, in the interest of the people generally, to think very seriously before you strike out this recommendation, because it seems to me extremely valuable and does not carry the weight of direction—it is not mandatory. It puts before every railway company and every engineer the question of safety for its trains and for the public. Therefore, I am in favor of it, as I am in favor of all other measures which promote public safety or the security of railway property.

Mr. Geo. W. Andrews (Baltimore & Ohio):—I feel that inasmuch as I took part in the argument last year in favor of the inner guard rail, that it is no more than right that I should say a few words now. As I said last year, I am heartily in favor of the inner guard rail, and my position is based not on theory but on practice that has been obtained in the maintenance of structures for thirty years. I could recall a number of cases where the inner guard rail has prevented cars, tenders and even engines from going over into the opening under the trestle or the bridge when so protected. We cannot take the stand, from an economical standpoint, that inner guard rails should not be advocated. I had the fortune during the past year to be connected with the General Safety Committee of our road. We visited a number of places throughout the country, and we found there was a public feeling against the railroad, because they had not taken action on the installation of certain safety devices because of the first cost. Now we all know that the placing of an inner guard rail on all bridges, especially on a road that has a great many, such as our road, with over 4,600, costs a great deal of money. One serious accident at any one bridge would come

very nearly paying for the entire cost of the guard rails, not mentioning the loss of prestige of the road, and it is for that reason that I speak heartily in favor of the installation of guard rails as fast as the conditions under which each and every road is laboring may permit.

We have to look upon this thing as much from the side of the public as we do from the standpoint of the railroad; we have to put ourselves in the position of a humanitarian in many cases. We have to say to ourselves, "Shall we help in every way possible to prevent accidents to our fellow-man, or shall we, to save a few dollars, take a chance?" I say we should not take the chance.

In closing I feel like reciting a few words by Sam Foss:

"Let me live in a house by the side of the road,
Where the race of men go by—
The men who are good, the men who are bad,
As good and as bad as I.
I would not sit in the scorner's seat,
Or hurl the cynic ban;
Let me live in the house by the side of the road,
And be a friend to man."

Mr. C. A. Morse (Rock Island Lines):—This subject of inner guard rails has been near to my heart for a good many years. I have insisted on their use, and with more or less success, but it is very hard to get rail for inner guard rails when it is hard to get it for sidetracks and other things that are needed badly. If we were all millionaires and had lots of money, it would be a good thing to have inner guard rails on sharp curves, and it would no doubt make a safer riding track, but we have not money enough for that, and no one would suggest that at the present time. The roads I have been connected with have had the rule that inner guard rails should be put on all through bridges, all steel deck bridges, all bridges on curves, and on all bridges one hundred feet or more in length on tangents; on main line and on branch lines where specially authorized. I do not think we are warranted in making the sweeping requirements recommended by the Committee; would also increase limit of speed of trains on branch lines, as there are few branches where passenger trains do not exceed twenty miles per hour between stations. I think we are liable to have legislation on this subject, and therefore think the recommendations of the Association should be what the railroads are finding practicable and not what is theoretically good practice.

Mr. John G. Sullivan (Canadian Pacific):—Some of the speakers misunderstood Mr. Lindsay and have misunderstood me, and being an Irishman, although born in this country, I have a right to explain myself. I am heartily in favor of the guard rail; we use them on all of our bridges that are over 100 ft. long; we use them on some curves and in some tunnels and at other dangerous points, but we are not so foolish as to make a rule and say that all curves, tunnels, etc., shall be provided with guard rails. It is to the interests of the company to avoid accidents, and we are trying to protect the company and in this way protect the public from the pettifogging lawyer, for in

the long run the public has to pay the bill. If this motion should carry and you fail to put in a guard rail at some unimportant culvert and an accident should happen in that vicinity, the fact that this is considered good practice by this Association may be the cause of the company having to pay a large amount of damages, which, of course, the public will have to pay in the long run. If we were voting on the question of whether we should use inner guard rails or not at certain points, there are not five men in this room who would not vote for the inner guard rail, but what we are voting on is whether or not this recommendation of the Committee shall go into the Manual regardless of conditions or whether the line is a straight line or whether trains are running fast or slow.

Mr. Chas. S. Churchill (Norfolk & Western):—Mr. Sullivan has covered the point that is in the mind of every objector. The Manual now contains the following statement:

"Guard Rail.—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track rail, to guide derailed car wheels."

Now, that recognizes the inner guard rail. The Proceedings heretofore have a great deal in them descriptive of the inner guard rail. Many plans have been published and good practice has been shown by those plans in the Proceedings. I believe the Association would make a mistake to adopt conclusion 2 in its present form, and that we are well protected by the form that is now in the Manual. The railroad with which I am connected has been using inner guard rails a great many years on bridges, curves and tunnels, but we believe as railroad men that we ought to be the judges, and certainly 20 ft. is too short a span for requiring the inner guard rail on solid-floor bridges.

Mr. Lindsay:—Mr. Sullivan and Mr. Churchill have voiced my sentiments exactly. On page 97 of Bulletin 162, section 20, we find the following specification, from the rules adopted by several states:

"Guard Rails.—Where physical conditions require their use, guard rails shall be installed in connection with derails. When used, they shall be placed between the track rails, parallel to and not less than ten inches distant in the clear therefrom, and must be of sufficient height, length and strength, and be properly secured to the track ties."

That gives some leeway for the exercise of good judgment. I am not opposed to guard rails. I favor them. I yield to no man when it becomes a question of the safety of the public, but I do think that we ought not to put the public to unnecessary expense. I would like to see that recommendation read something like this: "Where operating conditions warrant, a guard rail shall be installed on main track bridges of more than 30-ft. span—(a) on any track where the superstructure projects above the ties and adjacent thereto; (b) on single and double track structures; (c) on the outside tracks of multiple track structures.

Note.—Exception should be made in any case where the maximum clearance diagram of equipment does not provide more than 8-in. clearance from the structure.

The object of the inner rail is to prevent the equipment fro
ing the superstructure and doing damage to either. If the clea
the supporting structure is not sufficient to pass a derailed car,
the use of putting in a guard rail?

Mr. Carpenter:—I agree with a number of the speakers
should not call for inner guard rails on all structures. One p
has been brought out is that it does not make any difference i
to the length of the structure, but it does in regard to the wid
If your structure is as wide as the roadbed and strong enough
derailed equipment, I see no greater necessity for guard rail
structure than on the roadbed. I think that this feature of t
should enter into the recommendation in regard to the s
bridges.

Mr. Bachelder:—This body of men is better able to determ
specific length and specific speed than an individual. A number
here have argued that it should be left to the individual judgm
ought to be able to determine on something, if this recommendati
right. The Committee feel, from their study of the question, th
proper and we would be glad to hear some suggestions for char
recommendation.

Mr. Frink:—This recommendation has been under way tw
The first time one or more inquiries were sent out, about 61 rep
obtained. Of that number, 25 reported the use of guard rai
structures and 54 reported using them on some structures. F
remarks and other evidence submitted in answer to that circ
Committee felt at that time perfectly justified in recommending
of guard rails on all structures. It was not accepted by the co
last year, and the recommendation was returned to the Comm
further handling. The Committee sent out another set of inqu
result of which is briefly summarized in our report. We
329 inquiries and received answers from 165 roads. Those inqui
in all cases sent, as far as we could determine, to the official i
of construction or maintenance of bridges. Where they had
Engineer it was sent to the Bridge Engineer. In that circular
them to report on what they thought was the proper practice to b
mended, our idea being that the men who had been in that w
had specialized in it for years would be better qualified than ot
had not specialized in that work. Of the 165 replies we rec
per cent. reported using guard rails on all bridges; 71 per cent.
using it on some, and practically 11 per cent. on none. When it
the personal opinion of the members, 29.7 per cent. recommended
all bridges; 69.8 per cent. on movable bridges; 78.9 per cent. on
bridges; 65.5 per cent. on deck bridges; 57 per cent. on timber
and 36 per cent. on solid-floor structures. With the exceptio
solid-floor structures, more than a majority of the members rep
vised the use of guard rails. We have consulted the member

Association as closely as we could; we have gotten a great deal of information from them, and all of that information points to the general opinion of the members of the Association being in favor of the general use of guard rails.

I do not see how we could have brought in a different report from the information we had. Now, let me refer briefly to some other considerations. I assume that there is no question that this Association wants us to bring in a report in accordance with the facts, and whatever those facts are, if they believe that our report agrees with those facts, they want the report to go on record as being what we approve as good practice. We do not want to dodge the issue. One thing that bears on this subject is the action that has been taken by various civic bodies in regard to the use of guard rails. Mr. Lindsay has referred to the laws of New York State, imposing a penalty of $500 for each offense.

This is under the act of April 29, 1913, which reads in part as follows:

"Failing to cause guard posts to be placed in prolongation of the line of bridge trusses upon such railroad . . . or, in lieu thereof, failing to cause guard rails to be placed within the running rails of its track, or such other safeguard as the public service commission shall order, for the same purpose . . . is guilty of a misdemeanor, punishable by a fine of five hundred dollars for each offense."

In the Massachusetts laws of 1909, Sec. 58, page 25, par. 3, reads as follows:

"In order to prevent a derailed truck from running far from the track, even if it should be derailed before reaching the bridge, inside guard rails should be provided. These rails should be of the same height as the track rails and should extend across the entire bridge and for a distance of some 50 ft. beyond the ends, coming to a point in the center of the track, the point being protected by a casting or frog point. If there is a sharp curve on the approach, the guard rails should be extended around the curve. These rails should not be less than 8 in. in the clear, inside of the track rails, and should be securely spiked down to every tie. Such inside guard rails will in most cases guide a derailed truck safely across the bridge, a fact which has been repeatedly demonstrated in connection with steam railroads."

In the State of New Jersey, the Public Service Commission has asked to have guard rails placed on all bridges over 30 ft. in length.

In 1887 there was a bad wreck at White River Junction. I presume some of you may remember the editorial in the Engineering News at that time by the late A. M. Wellington, who was strongly of the opinion that the guard rail was an important protection to the bridge, and he took occasion to criticize the road for not having them in place. Some years ago there was a derailment at a drawbridge at Atlantic City and the Engineering News took occasion to criticize the construction of that bridge, referring at the same time to this accident at White River Junction. I do not think there is any question that any other accident that might be traceable to the same cause or was not traceable to that cause, but was on a structure without guard rails, would lead

to the same kind of criticism. I think the fact that guard have been used so universally would make it practically certai in case of a suit for damages the railroad would settle for damages. I do not think the action of the Committee in recomm the adoption of that conclusion would have any effect whatever on ble future damage suits, because I think the mischief has alread done. I do not see, from the information the Committee has gotte the various members who answered their inquiry, that it was pos bring in any other conclusion than that which we have brought

The President:—The question is on the adoption of the recom tion of the Committee on page 403.

(A rising vote was then taken on the adoption of the conclusi sulting in 115 votes for the adoption and 75 votes against the a of the conclusion.)

The President:—The next question is recommendations fo year's work.

Mr. Frink:—There is no need to make remarks about the fir ject. That was left over from last year, and you understand portance. In regard to the report on wooden docks and whar seems to me that is a vital question, because there are many docks and wharves all over the country which must sooner or l replaced by other types of structures. In regard to the other poi is a subject that Mr. Nelson, of the Seaboard, is interested in.

Mr. J. C. Nelson (Seaboard Air Line):—On the Seaboard Ai some seven years ago, the use of lag screws in connection with t an innovation to me. Like Mr. Sullivan, I was "ag'in the Gover on it, but after using them a few years, concluded it was the be of fastening that I had ever come in contact with. I think tha of us have found that bolts on guard timbers have been a serio sideration, and I suggested to Mr. Frink that it might be a goo to bring out, so that the Association might get the benefit of it.

The President:—The Committee will be relieved with the tha the Association.

DISCUSSION ON IRON AND STEEL STRUCTURES.

(For Report, see pp. 407-511.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON IRON AND STEEL STRUCTURES.

A. W. Carpenter.	W. H. Moore.
J. E. Crawford.	G. J. Ray.
W. H. Elliott.	A. H. Rudd.
E. A. Frink.	H. R. Safford.
A. J. Himes.	O. E. Selby.
H. S. Jacoby.	C. H. Stein.
B. R. Leffler.	E. B. Temple.
C. E. Lindsay.	F. E. Turneaure.

The President:—The report of the Committee on Iron and Steel Structures will be presented by the Chairman, Mr. A. J. Himes.

Mr. A. J. Himes (New York, Chicago & St. Louis):—The subjects assigned to your Committee during the past year are given in Bulletin 163, page 407.

Your Committee submits a final report on methods of protection of iron and steel structures against corrosion, in Appendix A. This report is submitted as information and without recommendation.

This subject is such a very broad one and involves so much detail and concerning it so much has been said, so many other investigations have been made, that this Committee thought best to compile a considerable amount of information, to give the references, and in general to indicate to the members the direction in which to look for information. It was our opinion that we could add little, if anything, to original information. We would be glad to hear the opinions, of those present, on the report, of the manner in which it has been treated, or any suggestions as to how it should be treated.

Mr. A. W. Carpenter (New York Central & Hudson River):—I cannot boast any Irish ancestry, but I find myself "agin the government" on certain features of this report. The feature to which I take exception is the portion of the report on pigments, given on pp. 412, 413, 414. The Committee has advanced a theory for the classification of pigments depending upon the action of pigments on steel in water, which is commonly known as the inhibitive and stimulative theory, and it has set it forth in such a manner as to make it appear as if it were a fully accepted theory, and has set forth a specific classification for different pigments, stated to be in common use, and then has drawn conclusions from this specific classification. Now, I believe that this theory is not fully accepted and that the Committee should have so stated, and I think that the classification shown in Table I is not proper to apply to commonly used pigments, even if the theory be accepted. I will state some reasons for my opinion in

connection with this table. It will be noted that preceding the table, at the bottom of page 413, it is stated, "Table 1 gives the classes to which commonly used pigments belong;" then follows the classification of pigments, the authority being named. It appears that this classification of pigments was made on a certain set of samples, representing one or more varieties or manufacturers' products of the different kinds of pigments named, and it does not at all follow that samples of other varieties or products of pigments known by the same general names would have given the same results and been similarly classified.

At the top of page 414, in the column under "Stimulators," you will note, graphite No. 1, graphite No. 2.

The common varieties of graphite pigments are not distinguished commercially by numbers and there are at least four or five in common use. You will also find two iron oxides, classified. There are many different iron oxides. There is no reason to believe that they will all have the same characteristics. The very common pigment for structural paint, red lead, is omitted altogther. It seems to me that that omission ought to at least be commented upon. As to some of the discrepancies in the theory, I want to call attention to the inclusion of Prussian blue, inhibitive, at the top of page 414, and in another column, Prussian blue, stimulative. I have seen steel test pieces which were painted with both those pigments, one classified as inhibitive, the other as stimulative, by this theory, and after five years' exposure, my opinion, as well as that of other observers, was that the Prussian blue stimulative pigment had given the best results. Again at the top of page 414, I see white lead, Dutch process, shown as inhibitive, and in the table on the other page, under "Indeterminates," I find sublimed white lead and sublimed blue lead. These same tests, which I referred to, included all three of those pigments, and the white lead, Dutch process, gave very much poorer results than the other two.

I, therefore, think that the Committee in reporting in this way, without stating in any way the limitations of the theory or classifications shown, is not offering the information in the proper shape to the Association. I hope that they will revise their report in these respects, because otherwise it will go out to the membership and be taken as something that is accepted by the Association.

The President:—Appendix A, page 412, is now open for general discussion. The Committee does not submit this with the idea of publishing it in the Manual, but desires to have it received as information. In view of the remarks by Mr. Carpenter it may be well for our membership to carefully read this Appendix later on and submit suggestions in writing. With this understanding we will proceed to conclusion 2, page 410. The chairman will speak of certain subjects which are not treated in that conclusion.

Mr. Himes:—With reference to the report on "Study the design of built-up columns, co-operating with other investigators and committees of other societies," I would say that we have now at Washington 18 columns

which have been fabricated for these tests. One of them has been tested in the presence of the Committee. We are hoping for more rapid progress in the future.

In view of the very great importance of the fifth subject, "Investigation of secondary stresses and impact," and the original nature of the material contained in this report, it is much to be desired that the meeting give a little time to its consideration. We have here Prof. Turneaure, who has acted as chairman of the sub-committee handling this subject, and as he can present the subject so much better than the chairman, I will ask that he make a brief statement concerning the accomplishments of that sub-committee.

Prof. F. E. Turneaure (University of Wisconsin):—The Committee did some experimental work in the field two years ago last summer, a brief statement of which was made in the report a year ago, explaining what work had been done, but giving no results. During the past year the Committee has worked out a number of theoretical analyses, and has also worked over the results of the field tests and brought together here such results of analysis and of the tests as could be got together in the time at its disposal. From a theoretical standpoint, the subject is a very large one, but it seemed to the Committee that the analysis of a few typical structures and a comparison of theoretical with experimental results where possible would be of considerable value to the Association. The report begins on page 437, with a brief statement of the various elements involved and the various kinds of secondary stresses that we studied.

(Prof. Turneaure read the six items on page 437.)

The discussion shows that secondary stresses due to rigidity of joints are quite as much real stresses as any other stresses that make up the total. On pp. 440-1 we have described some of the results of analysis and experimentation. (I will explain here that in getting together this report there were so many cuts that there was some confusion in bringing them together for binding. The report will read easier if you note that the cuts on pp. 448 to 451 inclusive, and 473 to 484 inclusive, should follow the text of the report, coming after page 491. The cuts I have just mentioned belong to the analysis of a typical structure, inserted merely as sample analysis.)

The results of the theoretical analysis begin on page 452. On that page is shown by the shaded diagrams the bending stresses or secondary stresses in the top chord of a deck Pratt truss, showing secondary stresses approximately 20 per cent. of the primary stresses. On page 454 are shown results of calculation of the secondary stresses in the top chord of a 396-ft. curved chord truss, the secondary stresses running as high as 60 per cent. being due to the very short panel length. The second diagram from the foot of page 454 shows what the secondary stresses would be if the sub-verticals supporting the top chord were lengthened a small amount.

On pp. 456-457 are shown the results on a riveted Pratt truss and a riveted Warren truss, of ordinary design, showing secondary stresses of about 20 per cent. as a maximum. The make-up of these trusses is given on page 455.

On pp. 458-459 are shown some very high secondary stresses on a sub-divided Warren truss. With panels of very short length, 12 ft. 9¼ in. in the lower chord, we get secondary stresses of 50 to 60 per cent. The top chord, with panels twice as long, shows only about 20 per cent.

On pp. 461-2 are shown, in a slightly different way, the results of calculations on another bridge of very short panel length. The panel length is only 8 ft. 4 in., and you will notice on page 461 secondary stresses running nearly to 100 per cent. The exaggerated curved lines simply show the directions of the curvature. On page 462 results are given with joints slightly eccentric, as actually built, while 461 shows the effect with the joints all concentric.

Perhaps the diagrams on pp. 464-5 are as interesting as any. These show in one case the calculated secondary stress in a 105-ft. riveted pony Warren truss, and in the other case the observed secondary stresses in the same structure. These are the best comparison we have had between the theoretical and observed stresses. I think that the results correspond as closely as you would expect in work of that kind. The experimental results were obtained by means of four extensometers placed on the four corners of the member and readings taken by photographic process during the passage of a slowly moving test train, whose movements could be closely regulated.

Other analyses, given on page 466, show interesting results as obtained for trestle towers. They show how the omission of the transverse strut will in some cases cause secondary stresses to be fairly high, while in other cases the effect is very small. In the one case the number of panels is even, and in the other case the number of panels is odd. That makes considerable difference as to the effect of the lateral strut on the secondary stresses.

On pp. 470-1 are brought together in a general way the results obtained from theoretical calculations on all of the structures that have been calculated, and which were of any value in this comparison. The diagram on page 470 gives the general results on bottom chords and tension diagonals. The ordinates show the percentages, and the abscissæ show the ratios of the widths to the lengths of the respective members. That is the largest controlling factor in the problem, the ratio of the width to the length of the particular members, the secondary stress being approximately proportioned to that ratio, but of course depending on the general design.

The next plate shows the same thing for top chords and end posts, and some brief conclusions are given in regard to secondary stresses that we have been talking of. The tables given on page 477 show the general conclusions regarding this type of secondary stresses, and indicate that from 30 to 40 per cent. of secondary stress may be expected in trusses with rigid joints, the amount depending largely on the ratios of the widths to the lengths of the members.

On page 485 and following pages are taken up special problems, such as the effect of the deflection of floor beams on the bending of posts, and the effect of the chord stresses on the horizontal bending of floor beams. On page 487 are shown some theoretical results, compared with observed results, a very fair degree of correspondence being indicated. There is also given a brief discussion of some of the other features.

The Committee feels that it has shown fairly well that the secondary stresses due to rigidity of joints are not a myth, but that they occur just as definitely and certainly as primary stresses, that while they are a little more difficult to figure, they are nevertheless real. It has also been shown that the ratios of secondary to primary follow some general laws which may be developed and expressed so as to control to some extent the design. While we do not expect to see secondary stresses calculated for all bridges, I think the Committee as a whole feels it is a rather important matter, and that the limitations of secondary stresses can and ought to be determined with a certain degree of accuracy, so that some general recommendations may follow, controlling these secondary stresses in ordinary design.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis) :—It is customary to give committees and sub-committees more or less perfunctory thanks for their work, but it seems to me that the work of Prof. Turneaure and his associates on the sub-committee deserves some special recognition. The sub-committee has furnished the Association with the results of scientific work which has involved great labor and devotion, and there is no reward in sight except what the Association sees fit to give them. I move a special vote of thanks to Prof. Turneaure and his sub-committee for this splendid report on secondary stresses.

(Motion carried unanimously.)

The President :—Prof. Jacoby, will you discuss this report?

Prof. H. S. Jacoby (Cornell University) :—I am not prepared to discuss the report, since the time has not been available to study it as thoroughly as desired. Probably at the next annual meeting I may offer some statements in regard to methods of computation of secondary stresses. During the academic year ending last June there was at Cornell University a graduate student who had four languages at his command, as well as the mathematical ability and interest which led him to select bridge engineering as his major subject of study and to write a thesis on secondary stresses. He made a critical comparion between all the methods of computation, which has been developed and it is interesting to note the results of his investigation. I am informed that in Europe one of the writers on this subject made some comparisons of methods, but that the results were not published.

It may be added that this student made an unusual combination of subjects by selecting geodetic engineering as a minor, in consequence of which he discovered the possibility of a new and simpler solution of the equations relating to secondary stresses which had not been noticed before.

(Adjournment to Wednesday, March 18th.)

Mr. Himes:—Yesterday afternoon the Committee presente features of the report which were of such a highly technica as to be properly appreciated by comparatively few. To-day present a portion of the report which is not so technical, but to do with operation. It is no less important, and to the pu probably of much greater importance.

The first paragraph on page 410 gives the subject covere pendix D as the "adaptation of designs of movable bridges and interlocking appliances required."

This subject has been carefully studied by a joint sub-c representing Committees II and III of the Railway Signal As and Committees X and XV of the American Railway Engineeri ciation, and the report, as presented in Appendix D, is recomme adoption. While this is presented by the Committee as a fina there is not a complete unanimity of thought on the subject, an two amendments will be presented by members of the Committ report is shown on page 492.

Mr. W. H. Moore (New York, New Haven & Hartford) members of the Committee feel that the paragraph, as printed, altogether the detail very often used in connection with a mite We feel that this mitered rail is very desirable in some cases, in lift bridges, on account of the smooth riding and absence of ing which it produces, and for this reason we suggest the changes in paragraph (c):

"(c) Rail End Connections.—For high-speed operation ov bridges rail ends should preferably be cut square and connected b sleeve or joint bars to carry the wheels over the opening bet end of the bridge and approach rails; the outside of the head of rail to be planed off to a minimum width of 2 in. for the length by the sleeve or joint bar. For lift bridges, rail ends may be cu and connected as above or by easer rails, or may be mitered. Mite shall retain the full thickness of the web to the points. For hi mitered joints should be trailing to normal traffic."

Mr. Carpenter:—I wish to second that amendment.

The President:—Before this amendment is discussed, let us the discussion of the introductory paragraphs down to (a).

Mr. C. E. Lindsay (New York Central & Hudson River) that the report of the Committee is hardly in shape for accep this Association. Instruction 6, on page 407, reads, "Adaptatio signs of movable bridges to signal and interlocking appliances The heading of Appendix D is: "Requirements for the Prot Traffic at Movable Bridges."

Either the sub-committee has enlarged the scope of its work not fully covered it. The sub-committee attempts not only to changes in designs of movable bridges are necessary to a signal and interlocking appliances required, but they attempt al into the physics of the bridge, which is beyond the scope instruction.

Mr. Himes:—I will answer Mr. Lindsay's comments by saying this subject was first proposed by the Railway Signal Association and the report has been formulated by representatives of that Association and by our Committee and Committee X, and the report is satisfactory to a majority of all of these committees. It is fair to presume that the parties who originated the instructions had in mind what they desired to secure, and in their judgment they have secured it. It is possible that some other words might have been picked out to describe precisely what was done.

Mr. A. H. Rudd (Pennsylvania Railroad):—If mitered rails are good for lift bridges, I do not understand why they are not good for swing bridges. The amendment offered provides for their use on lift bridges only. The Pennsylvania uses mitered rails on its high-speed swing bridges successfully; they are used by the Lackawanna in some places, and on quite a number of the other Eastern roads. I see now that the Committee recognizes that mitered rails might be used, and I would be glad if they would broaden that amendment so as to permit their use on swing bridges as well as lift bridges. The amendment goes into a good deal of detail. I offer as an amendment to paragraph (c), eliminating the words "cut square and," and eliminating the last clause, so it will read "or by easer rails to carry the wheels over the opening between the end of bridge and approach rails," and stop there. That will permit the use of either miter or square-cut rail and recognize both as good practice without going into the specifications very deeply.

Mr. C. H. Stein (Central Railroad of New Jersey):—I agree with what Mr. Rudd has said in regard to the use of mitered rails. I was glad to hear Mr. Moore of the Committee make the recommendation, but I feel that he did not go quite far enough; I think he should specify that miter ends may be used on the swing as well as the lift bridges. We have no way of judging of the necessities of the present, except by the experiences of the past. Our line has been using the miter ends for all of its swing bridges, as well as all of its lift bridges. I have in mind a certain connecting line over which our road runs that adopted a type of square joint similar to that recommended by the Committee, and after it had been in use for perhaps a year it had given them no end of trouble and annoyance. By way of interjection I might say that the construction of this bridge on the Connecting Line was under the supervision of a large trunk line. After the connecting rails were installed and the bridge was in operation, it gave no end of trouble. The Connecting Line approached us and asked if we would not make for them a set of our mitered rails, with castings, shoes, and so forth, and install it on this bridge, which we did. Prior to the installation of the mitered rails the square-cut joints gave them much trouble; I might say, on an average of two to three times a month. The bridge was out of commission frequently, so that readjustment could take place. The mitered rails that we installed for them have been in service about three years. It is a swing bridge. During all of that time I do not recall having heard of the interruption to a train due to mitered rails not fitting in place properly.

I would like to see the suggestion that Mr. Rudd made approve the mitered rail proposition apply in these recommendations to sw well as to lift bridges.

Mr. Himes:—I would like to say what the attitude of the comm is on this subject of mitered rails. The majority of the committe opposed to mitered rails on either swing or lift bridges. We a posed to them especially on swing bridges, because with mitere we cannot swing the bridge without lifting the rails. The lifting rails means that a certain length must be loose, held in position for by chairs. The Committee purposely raised the issue and recomm that for safety of drawbridge operation these loose rails at the a drawbridge be done away with. That is our recommendatio that is the important topic for discussion.

Mr. E. A. Frink (Seaboard Air Line):—I am sorry to see that passed as it is. The Seaboard has quite a number of drawbridg have been equipped with mitered rails for a number of years. we have had very little, if any, trouble over them. The rail, in connection with the lift bridge, gives you an excellent to provide your interlocking or signal mechanism with a detecto as well as rail lock, so that it prevents clearing signals until th are down and locked in place. In the mitered rails that we u ends of the rails are bent at the correct angle before the rails are n In that way we get very good wearing qualities, a very durable r

The President:—Mr. Rudd, do you wish to offer an amendment amendment?

Mr. Rudd:—I would offer an amendment to the amendmen "rail ends should be connected by solid sleeve or joint bars, or by rails, to carry the rails over the opening between the end of the and the bridge rails." I might say that with our locking devi signal cannot be given if the rail is up more than a quarter of an the rail must be locked down before the signal can be given rail is supported in the channel with the easer rail on the outside, have found for our four-track lines it is the most satisfactory ar ment. We have tried the other on one or two bridges—most of ou speed drawbridges are in the State of New Jersey, and on the P. B. but in the State of New Jersey the Commission permits a speed miles over these bridges, and that is the highest speed permitte any drawbridge in New Jersey.

Mr. Stein:—I second the amendment to the amendment, and I add further to what I have already said, that when I saw an in tion of the particular device I spoke of, the square joint, it impress profoundly, and I thought that it was the thing we would want f lines, but after it had been in operation for a few months I con we did not want anything to do with it. I do not pretend to sa the square joint is imperfect and should not be installed. I simply the Committee to permit railroads a certain amount of latitude i matter, so that they may adopt their own preferences. It may be ble, in the case to which I refer, that there was something wron

the balance of the bridge, or something wrong with the alinement that was responsible for the imperfection in the operation of the square joint. But the fact remains, nevertheless, that the joint did not operate properly and these people came to us and had us make for them in our shops a set of the mitered rails, castings, etc.

I want to refer to what the chairman said, to the effect that a majority of the Committee were in favor of the square joint and opposed to the mitered rail. In our experience, covering fifteen or twenty years with the mitered rail, we have never experienced any trouble on account of this rail being loose. I do not contend that the mitered rails never foul in coming down and land on top of the fixed rail. As Mr. Rudd has stated, if the rail is not in its correct position within one-quarter of an inch, and I believe on our line it is adjusted to one-eighth inch, we cannot lock up the rails, so that the mitered rails, practically speaking, have never given serious trouble. I do not know of any that have given any trouble or broken under traffic, and while the speed is confined to forty miles an hour over the drawbridge I have in mind, I am certain that the speed has not always been forty miles over this bridge. I think it has been as much as sixty miles. We have never experienced any trouble on the seven or eight drawbridges we have equipped with the mitered rail.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I wish to confirm what Mr. Stein has said concerning the mitered rails on drawbridges. We have some drawbridges in our territory, both on the Passaic River and the Hackensack River, where we have more than one hundred suburban trains passing each way over them each day. There is an immense amount of traffic in the river, and there is a very great amount of inconvenience on account of holding up our traffic, because of bridges being open during the busiest hours of the day. I am sure that we have never experienced any undue difficulty, which shows that the performance of the mitered rail is satisfactory. There is no trouble to speak of at all, and I would be very much opposed to seeing this rule go through as worded, unless the amendment which Mr. Rudd suggested, in regard to permitting the use of the mitered joint, is also incorporated in it.

Mr. Carpenter:—Referring to Mr. Rudd's motion, I am not clear how it will cover the mitered rail, unless he considers the mitered rail an easer rail.

Mr. Rudd:—It simply means that the mitered section would be connected with a sleeve or joint.

Mr. Carpenter:—A mitered rail at the opening to the bridge.

Mr. Rudd:—It would be carried over by the riser.

Mr. Carpenter:—You consider the miter an easer?

Mr. Rudd:—The miter, with an easer rail outside that.

Mr. Carpenter:—That, perhaps, would clear up that question, but I want to state that my experience with the lift rails has not been in accord with that of the other speakers. I know of a case of a bridge equipped with the most modern form of lift rails for swing bridges, fully inter-

locked, locks provided for the ends of every rail, and yet there accident on that bridge. A train was derailed. It was appar one or more of the lift rails was out of proper position, and t was derailed. Therefore, I have come strongly of the opinion high-speed operation the square-end, fixed-rail joint is better, as p more security, because there are less chances for trouble. It does as well as the mitered rail, there is no question about that, I th nevertheless, I believe it is more secure.

Mr. B. R. Leffler (Lake Shore & Michigan Southern):—The practice on the Lake Shore is to have square ends. A loose ra must be used with the miter rail on swing bridges, means a r 20 ft. long not fastened to the ties, and just how that can be in so as to show absolute security in case of a broken rail has shown.

Many years ago we used to have the old stub switch wi rails. Inventors later devised the split switch, one characteristi tage of which was an unbroken rail for one of the running seems to me to endorse the lift rail, which we would have to do nection with mitered rails on swing bridges, is recognizing, in at least, an old bad practice. As far as the smooth riding of is concerned, with the square-end rail there is a slight roughness the false flanges on the wheels, but there is no more roughness found in the crossing of other railroads or in switch frogs. seen mitered rails that were hammered pretty badly, the result depression or a rough spot at the end of the bridge; this is a which grows worse very rapidly after it is once started.

The experience that we have had is that, under the heavy a we are having to-day, the mitered rail will not hold up under tr ditions; that is, where the traffic is 60,000 lbs. axle load and may hold up under traffic of a few trains a day.

I think many engineers have a feeling that a mitered rail thing like a facing-point switch. On single-track railroads yo avoid this condition, and on double-track railroads you may ha either way.

Of course, one great advantage of the mitered rail in connec lift bridges is that you do away with considerable machiner the sliding bar and the sliding sleeve require. It reduces first c

Mr. E. B. Temple (Pennsylvania Railroad):—I would add test against the adoption of paragraph (c) as it stands. Mr. pointed out that all our important drawbridges are equipped wit rails, and they have an easing block outside to ease the wheel miter. In order that these two subjects may be treated in paragraph, I would suggest the following reading: "Rail ends cut square or mitered, and connected by sliding sleeve or joint I feel very strongly that this Association ought not to legislat the mitered rail, when it is shown that it has been used su and advantageously on a number of important railroads."

Mr. H. R. Safford (Grand Trunk):—It has not been made me from the remarks of Mr. Stein just what were the real

he had with the square-end joint. My personal experience leads me to believe that the square-end joint is a much stronger form of track structure, and the same reason for condemning the miter rail at the drawbridge holds as to condemning the miter rail for ordinary track use, namely, that the rail is weakened at that joint by reason of being cut in a diagonal direction. There is a type of miter rail, and perhaps that type is meant in this discussion, which is in effect a dovetail joint, but the rail is specially made so that the full supporting power of the web is maintained practically all the way through. However, if by mitered joint is meant a rail planed off at an angle, I am opposed to it. If it means a semi-miter or dovetailed miter (if that is a proper term to use), I have no objection to it, but it seems to me the straight miter has an element of weakness and should not be used. I should like to hear what the trouble was with the butt-end joint.

Mr. Stein:—The Central Railroad of New Jersey is not having any trouble with the butt-end joints, because they do not use any. The experience to which I referred was secured from a connecting line over which our trains run adjacent to our territory and the touble was due to the fact that the butt-end joint did not slide in proper adjustment, and it had to be pounded to get it in, consequently interrupting the entire bridge machinery. When I first saw the device it appealed to me strongly, and I thought it was something far superior to the mitered joint.

I will be glad to put Mr. Safford in touch with the case I have in mind where the butt-end joints did not work out satisfactorily, and where we substituted the miter-end joints we had used on all of our drawbridges.

I cannot allow the statement of Mr. Leffler to go unchallenged when he says he thinks the miter joints are all right when they do not have many movements. I want to say for his enlightenment and the eludication of those who will vote on this subject and do not have any drawbridges on their own lines to contend with, that on one particular bridge which we have over Newark Bay, we have from 250 to 300 movements in each direction each day; there are sometimes more than 600 trains which pass over this bridge each day. At least 200 of these movements are high-speed movement running around forty miles an hour, and sometimes in excess of that. With all of our experience with the miter rails we have had no difficulty to speak of, and only occasionally would they fail to drop properly into their proper positions. They may bind, perhaps, a little on the shoe, but with just a little touch of a hammer or bar, it will set them in proper position. Under no circumstances could you lock up the bridge until the rail was within ⅛ in. of where it belonged. I think we only allow for an adjustment of ⅛ in. in these rails.

I think in the case that Mr. Carpenter referred to, he wants to go after his signal department to get more modern interlocking. I cannot possibly see how they could have locked up this bridge and given the signal if each one of the mitered rails was not in exact position for the

movement. It should have been impossible to have done t
something was out of order about the interlocking arrangem
permitted it.

Mr. W. H. Elliott (New York Central & Hudson Rive
representative of the sub-committee of Committee X, which
report, I would say, from a signaling standpoint, it is o
that either arrangement of rail ends may be interlocked
security, so that discussion of the subject of supporting or c
wheel across the gap should be from a track standpoint rath
a signaling matter.

Mr. Leffler:—The question of maintenance is a vital point
be interesting to know how many times the rails have to be re
pecially where there are 600 trains a day. Another advant
square-cut rail is the allowance for expansion. A gap of 1
can be allowed. With the mitered joints you can, of course,
expansion, but the edge of the miter will cold-roll and tro
to some extent.

Mr. Himes:—It might appear from the discussion that
joint, which has been proposed by the Committee, did not o
cessfully. I wish to disabuse the minds of the members of
ciation from any such idea. A very large number of them
cessful operation and have been for years. I might say th
was Bridge Engineer on the New York, Chicago & St. Loui
we were obliged to rebuild several of our drawbridges, a
capacity as Bridge Engineer I looked into the subject as tho
I was able to do, and eventually decided on this sliding joi
been installed and used successfully on our bridges for a
years. It is true that you cannot operate the sliding sleeve
rails are properly centered, and in order to secure that we h
at the end of the bridge, a jacking device, which centers
absolutely, so that there is no difficulty whatever about the o
the sliding joint.

As to the expense of the device, of course, it does cost
more than the plain mitered rail, but the cost is an exceed
percentage of the entire cost of the drawbridge, and I am sure
roads having large numbers of drawbridges, and whose repr
have spoken in opposition to this clause, would not stop for an
the added expense, if thereby they might secure greater sa
work of the Committee has been carried on in full view of the
tion which has developed in recent years pertaining to the
railroad traffic, and in particular the safety of traffic over dr
There has been a great deal of discussion of the subject, and i
our aim to present to you the best device which we can find
against, not an accident every day, a great number of trivial acc
any single great accident which might involve the loss of many
large sums of money.

In spite of all that has been said in opposition to this
it remains true, as anyone can see, that with a loose rail at the

drawbridge, if peradventure at any time that rail should be broken square across—and such a case is not unknown in railroad operation—the signaling and interlocking would not prevent a wreck. The strongest merit of the sliding joint is that it permits the rail to be spiked right up to the end of the bridge.

Mr. Rudd:—The drawbridge is a place where you can spend money to better advantage perhaps than anywhere else. That is, no expense should be saved in making the drawbridge safe, but I do not believe the sliding joint will cost very much more than the devices we use on our high-class drawbridges. I presume we are spending as much or more on our protection than is spent for the sliding shoe suggested. It is not a question of economy. It is a question of effectiveness. On our single-track lines we use square-end rail, but on double and four-track lines we use the miter rail, because we get better results and can run at high speed, and, in our opinion, with less danger. I do not believe anybody is more anxious for safety first than the Pennsylvania Railroad.

The President:—The question is on the amendment to the amendment proposed by Mr. Rudd. The paragraph as it will be under the amendment, reads, "Rail ends should be connected by sliding sleeve or joint bars or by easer rails to carry the wheels over the opening between the end of the bridge and the approach to the bridge;" that is, eliminate the words "cut square and" and eliminate the last clause.

(The amendment to the amendment was carried.)

Mr. Stein:—Please explain the substance of the motion as it stands.

The President:—As it now stands, the amendment to the amendment offered by Mr. Rudd has been adopted, and that amendment is practically a substitute for the motion of Mr. Moore, and Mr. Moore's motion is practically a substitute for the recommendation of the Committee. If you vote in the affirmative on the next motion, paragraph (c) will read as outlined by Mr. Rudd.

(Paragraph (c) was then adopted.)

(Paragraph (d) was adopted as read.)

Mr. Carpenter:—I would like to offer an amendment to the section on guard rails. I think the section as written is too narrowly defined. There are differences of opinion as to how guard rails should be constructed and there are different details best to be used for different locations. My amendment is, "guard rails should be provided as for fixed bridges, except for the necessary breaks at the ends of the draw span. Obstructions to derailed wheels which are guided by the guard rails should be reduced to a minimum."

Mr. Lindsay:—I second the amendment.

Mr. Stein:—I would like to ask whether the Committee will accept this phraseology in the sixth line, "There should be a clear space of not less than 8 in. between the head of the guard rail and the gage side of the main rail." I would like to know the reason they specify 10 in. My suggestion will not change the sense of the paragraph at all.

Mr. Carpenter:—That is one point that I would criticize this specification on: We are constructing a drawbridge now where we are placing

the guard rails about 4 in. clear from the main rails on account
an entirely different arrangement for guard rails. We are
re-railing device and the close spacing of guard rails which
it. We think that in case of derailment the mechanism for
connections would suffer less damage with that scheme of g
Therefore, it seems to me that a very narrow and fixed determi
to just how the guard rail should be constructed is out of pla
specification.

Mr. J. E. Crawford (Norfolk & Western):—If a mot
order, I would move that this whole subject be withdrawn f
sideration this year, and be postponed until next year. I fe
first place, that there have been some amendments offered
not been fully considered, that these recommendations as w
too positive, they should be more in the nature of recommende
than of a specification.

The President:—We will entertain that motion after disposi
Carpenter's motion, unless Mr. Carpenter will withdraw his mo

Mr. Carpenter:—I will withdraw my motion.

The President:—The motion before the house is that of M
ford. Before putting the motion we had better know what
mittee desires to have done with that portion of the report on
The motion is that Appendix D be recommitted.

(Motion carried.)

Mr. Lindsay:—I feel that the subject of clearances is inti
lated to the same subject pending before the Committee on E
and I move that it be referred to the Committees on Iron
Structures and on Electricity for joint consideration and actio

Mr. Himes:—The Committee submits two additional clause
inspection of the fabrication of steel bridges, page 410.

Also, additional clauses for the inspection of the fabricatio
bridges, on the same page.

The Committee moves that these subjects be adopted and
in the Manual.

(Motion carried.)

Mr. Himes:—The recommendation of the Committee as to
the coming year is that we continue the study of built-up col
design and length of turntables, the study of secondary stresse
pact, and also to take up the consideration of live load an
formula.

Mr. Chas. S. Churchill (Norfolk & Western):—With refere
inner guard rail conclusion adopted yesterday, the fact we do
a definition for bridges leaves us in the shape of having adopt
clusion, the application of which we cannot correctly determin
ever in order, I would like to have that action reconsidered.

The President:—The Chair would call attention to the fact
is a Committee that has a very large attendance and it sets an
example for all the committees of the Association. The Co
dismissed with thanks.

DISCUSSION ON MASONRY.

(For Report, see pp. 513-568.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON MASONRY.

MAURICE COBURN.
RICHARD L. HUMPHREY.
HUNTER MCDONALD.
H. R. SAFFORD.
G. H. TINKER.

The President:—The report of the Masonry Committee will be presented by the Chairman, Mr. G. H. Tinker.

Mr. G. H. Tinker (New York, Chicago & St. Louis):—The Committee has had under consideration during the past year three subjects, "Waterproofing of Masonry and Bridge Floors," "Disintegration of Concrete Structures" and "Principles of Design of Plain and Reinforced Concrete Retaining Walls, Abutments and Trestles." The subject of waterproofing of masonry and bridge floors has been under consideration by the Committee for the past five years. We have presented progress reports, and in 1912 a bibliography of the subject. This year we present a final report with recommendations as to approved practice, which we ask the Association to adopt and order published in the Manual. The subject of disintegration of concrete structures has been under consideration for two years and we present this year a final report with recommendations. The Committee has had under consideration for several years the subject of "design of retaining walls, abutments and trestles." We have not been able to make very much progress. Some years ago we presented a report showing typical examples of designs of retaining walls, with an analysis of the stresses in the same from a mathematical point of view. We had also some examples of walls which had failed, with an attempted analysis. During the last two or three years the Committee has tried to inaugurate a series of experiments to determine practically the pressure of earth upon retaining walls, but inasmuch as this requires the expenditure of some money for apparatus, we have not been able to accomplish anything as yet. We still hope to be able to make some such experiments. There will be an opportunity during the coming season for experiments upon walls of 30 to 40 ft. in height, and we hope to be able to raise funds to start these experiments.

The report upon the subject of waterproofing of masonry and bridge floors will be found on page 156. It contains a statement of the scope of the subject, with a description of the different methods of waterproofing and the materials which are used. Following this are certain conclusions which we ask the Association to adopt. Following these is an appendix, in which the general subject is again treated in greater detail. Extracts from various sources are given concerning the use of the different waterproofing materials and the results obtained. The Committee asks the Association to adopt the conclusions on page 536.

Mr. Maurice Coburn (Vandalia Railroad):—In the first line
paragraph it says, "Of either asphalt or pure coal-tar pitch in
tion with felts and burlaps." There is nothing said about the qu
the asphalt. In connection with the felts, a mistake has been
speaking of felts and coal-tar pitch. It is not coal-tar pitch, but
In many places asphalt is not thought to be the proper waterproo
there are many places where coal tar is not the proper water
and where asphalt would give better results. I would move t
paragraph be amended to read, "Membrane waterproofing of a
bitumen in connection with either felt or burlaps, or both."

Mr. Tinker:—In stating the conclusions regarding this p
method of waterproofing in one paragraph, the Committee assur
members would refer to the body of the report in which these
are gone into in detail. It is there shown that asphalt may be
different combinations, either with or without burlap, and with
numbers of layers. There are specifications for the quality
material, specifications for asphalt; and it is also stated that
pitch is not the best material in all instances, and neither is
Sometimes asphalt is preferable and sometimes coal tar. By rea
body of the report it will be seen that this is brought out in det
conclusion simply says, "Membrane waterproofing, of either as
pure coal-tar pitch, is good practice." We did not think it n
to go into a great amount of detail in the conclusions.

Mr. Coburn:—My amendment does not require that any of
clusions should go into detail.

Referring back to the body of the report, I do not think
ferences between the materials is properly brought out. Ther
good many changes that should be made in the body of the rep
page 519 the word "pitching" is used in connection with "asphalt
may be a common term, but people in the business do not seem t
stand it. Under the heading "asphalt mastic," on page 519
emphasis is not given to the preparation of the material. I do n
the matter has been properly brought out. It does not seem to
the difference in the qualities of coal tar and asphalt have be
erly stated. It is the general opinion that asphalt is warr
the waterproofing of a solid floor bridge and that coal tar is n
put there at all. A good many people think that most aspl
not first-class material in underground waterproofing. On p
in the third paragraph, it is stated, "It is generally found to be
to obtain coal tar of good quality." That is what the asphalt
tells you before he has been in your office five minutes. I do n
it is any more difficult to get good coal-tar waterproofing than
get good asphalt. On page 522, under "felts and burlaps," th
"coal tar pitch" should not be used, but "coal tar." In this co
"wool" felt is the common trade term. I think the word
preferable. On page 523, about the seventh paragraph, I think
should be brought out that coal tar has antiseptic qualities and

the rotting of felt, particularly burlap, while in asphalt there is nothing that protects it. The asphalts are not antiseptic. On page 524, it seems to me that an attempt is made to draw a general specification for all sorts of bitumen, and that is a hard thing to do. On the top of page 525, some of the prices are not right.

In the fourth paragraph, page 439, there is a direct quotation from the roofing report, except that the statement in the roofing report referred to Trinidad asphalt alone, and this paragraph refers to all asphalts. I have seen it stated that all asphalts are affected by water, but the best opinion does not agree with that, and I believe that it would be a very difficult thing to demonstrate.

The statements about fluxes quoted on the last part of page 539, were taken from Prof. Baker's book. They are not now a correct statement of the situation in regard to fluxes.

When we come to the appendix, with the quotations from other people, it seems to me that the Committee has not used a proper degree of accuracy in this matter. When a quotation is made the dates should be given, and it should state who the man is, and if he has any connections with the manufacturers.

In the fourth paragraph, page 539, Prof. Baker's discussion of bitumen was made in connection with roads and pavements in 1902. At that time it was probably the best general discussion of bitumens in this country. Now it is out of date. On page 541, there is a discussion by Clifford Richardson. It seems to me that it ought to be stated that Clifford Richardson is an employee of the Barber Asphalt Company, and that the specification he proposes is clearly a specification for Bermudez asphalt. There are several other instances of that same sort. Where there are quotations that ought to be made plainer, as to where they came from, and the date should be given. On page 547, next to the last paragraph, it speaks of the test of Westinghouse, Church, Kerr & Co. as to waterproofing. That would be a good test for roofing, but is not a good test for waterproofing.

The President:—The question is on the amendment offered by Mr. Coburn, reading, "Membrane waterproofing of a suitable bitumen in connection with either felts or burlaps or both."

Mr. Richard L. Humphrey (Consulting Engineer):—Mr. Coburn is right in some of his statements; both asphalt and coal tar are suitable for some purposes and not suitable for others, as has been shown by the experiments made by the United States Geological Survey. The term "bitumen" is elastic and incorrect. The paragraph ought to go back to the Committee for further consideration. The amendment proposed by Mr. Coburn does not meet the situation at all. I offer the amendment—

The President:—The Chairman will read the next.

(Mr. Tinker then read paragraphs 3, 4, 5 and 6.)

The President:—The Committee moves that conclusions 1, 2, 3, 4, 5

and 6 on page 536 be adopted by the convention and published in the Manual.

(Motion carried.)

Mr. Tinker:—The Committee wishes to offer a revision of conclusion on page 568, as follows: "Concrete to be exposed to the action of sea water, or alkali waters, or gases containing sulphur, or in which reinforcing metal is embedded, should be dense, rich in Portland cement and allowed to harden under favorable conditions before such exposure."

Also a revision of conclusion No. 2: "Concrete to be in contact with alkali waters should be made with aggregates inert to the alkalis in the water."

The President:—The Committee recommends the adoption of conclusions 1, 2, 3 and 4, as amended, in accordance with its own motion, and that these conclusions be published in the Manual.

(Motion carried.)

The President:—The Committee will make a statement as to its recommendation for its next year's work.

Mr. Tinker:—We expect to endeavor to get a start on some of the experiments on earth pressure upon retaining walls. We also intend to revise the specifications for concrete and reinforced concrete, not very extensively, but in some small parts. The subject of specifications for Portland cement and the methods of testing cement will be largely overhauled by the committees having such matters in charge. The matter is mainly in the hands of Committee C-1 of the American Society for Testing Materials. Committee VIII will appoint representatives who will act with Committee C-1. It is probable that within the next few years these specifications will be largely rewritten. Outside of this the Committee has no definite plans for undertaking any new work. We would be glad to have suggestions.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I would suggest that the Committee be instructed to look into the advisability of spouting concrete by adding an excess of water.

Mr. H. R. Safford (Grand Trunk):—In reference to the adoption of conclusions on waterproofing bridge floors, notwithstanding the time the Committee has devoted to this subject, it seems to me it has been left in rather unsatisfactory shape. I think that the Committee should continue their investigations and see if it is not possible to get a set of specifications or rules regarding the waterproofing of bridge floors which shall be acceptable and which the majority of the members of the Association will use.

The President:—The Committee is relieved with the thanks of the Association.

DISCUSSION ON TRACK.

(For Report, see pp. 569-606.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TRACK.

Curtis Dougherty.
W. H. Elliott.
E. T. Howson.
J. B. Jenkins.
E. R. Lewis.
Hunter McDonald.
Edwin F. Wendt.

(Vice-President Storey in the Chair.)

Vice-President Storey:—The report of the Committee on Track will be presented by the Chairman, Mr. J. B. Jenkins.

Mr. J. B. Jenkins (Baltimore & Ohio):—I will introduce the report by reading the first part.

(Mr. Jenkins then read paragraphs 1, 2 and 3 on page 569, and conclusion 1 and moved its adoption.)

(Conclusion 1 was adopted.)

(Mr. Jenkins read conclusion 2, and moved its adoption.)

(Conclusion 2 was adopted.)

(Mr. Jenkins read conclusion 3, and said:)

This is simply a concise statement of speeds through level turnouts with which each individual can compare his own notions as to the proper speed. For instance, No. 11 turnouts with the 22-ft. switch point gives a speed under these conditions of 27 miles per hour, while No. 16 gives a speed of 40 miles per hour. If, in your estimation, the speed for No. 11 should be cut down to 20 miles an hour, No. 15 should be cut down proportionately. If, in your estimation, the speeds for No. 11 could be exceeded 50 per cent., those for No. 16 should be exceeded 50 per cent. The speeds given here are strictly consistent.

(Mr. Jenkins read the section of the conclusion relating to the matters to be received as information and said:)

The Committee is not ready to report finally on plans for slip switches, but has presented its ideas in three typical plans, and has also presented another idea which has been worked out by the Big Four Railroad, which embodies the distinctive feature of staggering the switch points in order to take care of the interlocking rods. The Committee considers this feature as worthy of special study.

(On motion, that part of the report was received as information.)

Mr. Jenkins:—The Committee's recommendations for further study are embodied in the last part of the conclusions. The third subject is "Economics of Track Labor." There is one matter, in connection with that subject, which is not strictly economics of track labor, but

very closely related to it. We have touched upon it in the ge program for future work of the Committee, found in the report, 588, item (9) "A study of the matter of proper season for va kinds of track work." The date of the beginning of the fiscal has a great deal to do with the season at which the track work is As the fiscal year begins July 1st, it is very common to have tenance expenditures postponed from the spring until the fall, thr the work into a season of the year when it cannot be done as when labor is scarce, and when the roads which began the work in the spring have secured the pick of the labor; also, i fall the labor is largely employed for harvesting and other pur The track work is left in a rather uncompleted state when comes, and in many cases the track cannot be brought into condition until spring. I do not think it is any exaggeration t that for every dollar of expenditure postponed in the months of May and June, it will require about $2 to be expended in July, A or September in order to put the track in the same condition it have been if that money had been expended at the proper time, makes about 400 per cent. interest on the money.

By the simple expedient of changing the fiscal year, we not be under the necessity of postponing our expenditures for maintenance and could spend the money at the time it could b to the best advantage.

Further, in connection with this same subject of economic track labor, referring to Exhibit C, the Committee has undert the work of deriving some factors for equating the track mil and a few roads have already undertaken this to some extent, an them the Baltimore & Ohio, which has accomplished considerable a this line; but the information is exceedingly scant so far, and the C mittee thinks it a very important subject.

There are too many roads on which the maintenance expendi are apportioned purely on a mileage basis, perhaps too much n spent in some places where the money is not needed, and entirely too money spent where it is needed. We should try to arrive at some tical method of apportioning the proper amounts to the various di of the road, and if the information called for in Exhibit C is s to the Committee, it will furnish us the basis for obtaining the factors and enable the railroads to apportion the money for work to better advantage in the future. We wish to ask the co-operation of every member of the Association in compiling formation shown on Exhibit C.

The Vice-President:—Are there any suggestions in regard work of the Committee for next year?

Mr. Curtis Dougherty (Queen & Crescent):—I note tha Committee has under consideration the matter of standard guar and that it will continue to have this matter under consideration the coming year, according to the recommendations. I desire t

on the Committee that they should endeavor to arrive at a definite recommendation on the matter of guard rails, if possible, for next year's report, considering the length, the matter of guard rails on tangents as well as on curves, and the proper height of the guard rail relative to the main track rail.

Mr. W. H. Elliott (New York Central & Hudson River):—I wish to refer to Exhibit B, extending the duties of section foremen. This work is also being undertaken by Committee X, under the title "Economics of labor of signal maintenance," and I suggest that a sub-committee of the Track Committee be appointed to confer with a sub-committee from Committee X. We feel that the two committees should work together on this subject and that the results derived from such co-operative work will be greatly to the advantage of both committees.

Mr. E. R. Lewis (Duluth, South Shore & Atlantic):—It appears to me that there is likely to be some misunderstanding, even among the officers of railroad companies, of the progress report on this subject if it is left as it stands. I am sure it is not the idea of any member of the Committee that the section foremen, with the amount of knowledge that these men now have, and the help which they have at their command, will be expected to take care of signals, bridges and buildings. I think the Committee's suggestion that road foremen be appointed, who shall have charge of all work over short districts or sections, including the track, bridges, buildings and signals, seems the most likely solution of the problem. I do not think any staff alteration less than that would be practicable. To my certain knowledge, for twenty-five years the officers of railways, from the lowest to the highest, have now and again increased the scope of the section foreman's duties to the detriment of track maintenance; and this same statement holds true to-day. I am sure that it is not the intention of the Committee that this mistake be enlarged upon. It is unjust to the section foreman: he must have some special education to prepare him for these new duties and must have proper help to perform them. At the present time he is the hardest-worked man on the railroad, not only physically, but mentally. He works all day with his hands and he spends half the night on his clerical work. I do not think there is any body of men in the railway service who do the work which the section foreman does day after day, or who have greater responsibility.

Another point of view is that it would not be safe to increase his work. We have heard a great deal in the last year or two about "Safety first." The way to keep a track safe is to keep the trackmen on the track. Every minute you take them off the track you leave the track unsafe. Every hour's work taken off the track, every hour that you take the section foreman away from the track, is lost and will never be regained. There are so many days' work in the year. When a day of track labor is gone, it is gone forever. Unless provision is

made for ceaselessly patrolling the track by men under this roadway foreman, or whatever he is to be called, we will handicap progress.

Mr. Jenkins:—The Committee has made no recommendations in regard to this matter. The Committee considers it a large subject and has only started to make investigations. We have very little information on the subject. It may be possible the Committee will not undertake to say that it is advisable—the Committee is just as likely to recommend against this as for it. It may be possible that it may be found that some economies, perhaps some increase in safety, can be brought about by putting a high-class man in charge of the section gang, a man who understands the signals as well as the track, and have an assistant foreman to look after the track and road, leaving your track gang unimpaired; putting under your section foremen all the men necessary to do the little jobs of carpentering, attending the signals, and everything of that kind that is now done by men who travel 500 miles to do 50 cents worth of work. The question is an open one, and the Committee has as yet no mind on the subject.

Mr. Lewis:—What I said was not made in a spirit of adverse criticism of the report of the Committee, but to call attention to the fact that the section foreman has not had much said for him in probably twenty years, and I am sure that this Committee will be glad to do him justice.

The Vice-President:—It is my understanding that this is a progress report only, and consequently is not up for discussion at the present time, having been adopted as a progress report. The suggestions of Mr. Lewis will be given consideration by the Committee when it brings in its further report.

Mr. E. T. Howson (Railway Age Gazette):—I would like to emphasize and endorse what Chairman Jenkins said about a study of the influence of the present fiscal year on the economics of our present track labor. Over 55 per cent. of the total maintenance expenditures of the railroads is for labor, and over 46 per cent. of all maintenance expenditures is for track labor The greatest deterrent to the economical expenditure of this 46 per cent. for track labor to-day is the termination of the fiscal year in the center of the natural working season. Under the present financial conditions existing on the roads, many of them find it necessary to limit the expenditures very severely during the first half of the working season up to July 1st. After July 1st the forces are enlarged in an endeavor to do the work which should be done before winter. If the ending of the fiscal year could be changed to some other date, perhaps to correspond to the calendar year, these disturbances and interferences would be eliminated and the track work could be conducted through the entire working season, the natural season for this work, which is in the spring and summer.

The advantages of a change of this kind are evident to any man who has to pare down his forces in the spring and then build them up in the fall, not only in securing greater economy of labor, but in the

better handling of material as well. These advantages amount in the aggregate to large sums, into millions of dollars. One Vice-President told me last week that he believed if he could get away from the effects of the fiscal year he could reduce his maintenance expenditures one million dollars, or practically ten per cent. of his total maintenance expenditures.

A study of this subject through this Association, whose membership sees most directly the detrimental results of the present practice, would be valuable. This Association could impress on the executive officers of the railroads the advisability of a change in the date, by showing the savings that would be possible by such change. The termination of the present fiscal year is a purely arbitrary date for accounting purposes, and while there would necessarily be some adjustment, after it was changed I believe the operating and maintenance officers could show such a large saving that the change would be warranted from every point of view. I would second Mr. Jenkins' suggestion on this subject most heartily.

Mr. Edwin F. Wendt (Member Engineering Board, I.C.C.) :—I have endeavored to ascertain what reasons led to the selection of June 30th as the closing date of the fiscal year, but have been unable to find any good business reason. It has been said that the railroads favor this date. If this is the case, I am sure that Engineers could not have been consulted in regard to this matter; therefore, I wish to most heartily endorse the suggestion of the Track Committee that this is a question for discussion on the part of Engineers and as a result of their study it seems to me that a recommendation could be made which would be valuable.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis) :—I hope that the Association will decide to take this matter up, and I fully endorse the idea. I hope, however, that we will have better success with it than we have had with the question of brine dripping.

The Vice-President :—The Committee is excused with the thanks of the Association.

Mr. E. E. R. Tratman (Engineering News, by letter) :—The insistent demand upon the railways to-day is for increased economy and efficiency, and in maintenance work it seems probable that these results may be obtained by consolidating or correlating the various maintenance forces to some extent. One member considers that it would be unsafe to let men leave the track-work for other duties. But the track is left to itself at least 14 hours per day, and if a rainstorm comes along the sectionmen will leave the track and get shelter. A road that would adopt this combined maintenance system is not likely to have track in such condition that it is not safe to let one or two men leave the section gang while they repair a station platform or fix a pump house or repair a bridge floor. In fact, it seems to the writer that the system offers advantages specially to the progressive road, which is giving thought to the problem of combining efficiency, economy and safety in greater de

gree than before. Incidentally, the "safety movement" must not be carried to extremes. Railways are not built *for* safety, although they should be operated *with* safety. They are built to carry traffic, to accommodate the public and to earn a return on the investment, and safety is only one of many items in the problem of operation. While it is too early to express a decided opinion as to the proposed change in the maintenance system, it certainly appears to offer advantages that make it worthy of careful consideration.

DISCUSSION ON ELECTRICITY.

(For Report, see pp. 609-624.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ELECTRICITY.

G. A. HARWOOD.
E. B. KATTE.
C. E. LINDSAY.
J. C. MOCK.
E. B. TEMPLE.

The President:—The next business is the report of the Committee on Electricity. In the absence of the Chairman and Vice-Chairman of the Committee, Mr. G. A. Harwood will present the report.

Mr. G. A. Harwood (New York Central & Hudson River):—The report of the Committee this year is brief, containing only one recommendation, but it is felt that that recommendation is important in the development of the standardization of clearances on steam railroads which are electrified or to be electrified.

The American Railway Association wishes the diagrams acted on by this Association and American Electric Railway Association before it passes on them, although its Committee will recommend them.

Some considerable progress has been made on a possible modification of a third-rail clearance diagram to permit space for automatic train stops or other structures.

The table on third-rail clearances has been corrected up to date.

A very considerable start has been made on the subject of electrolysis, a Joint National Committee having been appointed, and since the report was written some further progress has been made. I will ask Mr. Katte, who is the Chairman of the sub-committee on Electrolysis, to advise the meeting what has been done.

Mr. E. B. Katte (New York Central & Hudson River):—Since the report was printed, two meetings of the Joint National Committee on Electrolysis have been held in New York, and the National Bureau of Standards, the American Gas Institute and the Natural Gas Association, which had not previously sent delegates, have now appointed members and are represented on the Joint Committee. The American Water Works Association is the only one of the larger associations interested in electrolysis which has not joined in the work. They are holding out because they feel that their interests were opposed to those which have been active in bringing together the various associations. They have, however, recently been approached by representatives of the Gas Institute and the Natural Gas Association and the Telephone and Telegraph companies, and it is hoped that before the end of the summer they will also send delegates to the Joint Committee.

The National Bureau of Standards has appointed Dr. E. B. Rosa, the chief physicist of the Bureau at Washington, as its representative

and he has consented to serve as the Secretary of the Committee. A Committee on Plan and Scope was appointed which reported at the last meeting of the Joint Committee. Perhaps an extract from this report will give you an idea of the kind of work the Committee is to take up. I quote from the sub-committee on Plan and Scope as follows:

"We recognize the existence of electrolytic injury due to stray earth currents. An important object of this Committee should be to promote harmony between the interests affected and which might be threatened by disputes on account of electrolytic injury.

"We believe that in general the prevention or cure of electrolytic trouble can only be secured to the fullest extent by a spirit of co-operation between all interested parties:

"(a) In ascertaining all the pertinent facts;

"(b) In preventing the undue airing of disputes in the press;

"(c) In determining the best remedy for any trouble that may be found to exist from an engineering and a non-partisan standpoint.

"We do not believe it to be the province of this Committee to decide matters at law. Therefore, it should exclude from its consideration all questions as to the legal rights of the respective parties. We do not believe it to be the province of this Committee to act as Consulting Engineers and prescribe special remedies for individual cases of troubles."

The Committee on Plan and Scope recommends four subjects to be considered. These are to be considered by sub-committees. When these committees were appointed the three representatives of this Association received assignments to them of the sub-committees. The work of the sub-committees are divided in this way: First, principles and definitions; second, methods and analyses of surveys; third, foreign practice; fourth, domestic practice.

The Committee on Principles and Definitions is to prepare a definition of "electrolysis" as it is to be considered by the General Committee and provide an elementary treatise on the theory of electrolytic damages. The Committee on Methods and Analyses of Surveys is to set forth the kind of information to be obtained when an electrolytic investigation is to be made and to prescribe in general the recommended methods of procedure in order to obtain it; also, this Committee is to prepare in convenient form, useful statistics of various classes of pipes, rails, cables, etc.

The Foreign Practice Committee is to collect and compile full information on the manner in which electrolysis problems are dealt with in foreign countries, including regulations prescribed and the practice of the interests concerned.

The Domestic Practice Committee is to collect and compile full information on the manner in which electrolysis problems are dealt with in America, including regulations prescribed and the practice of the interests concerned.

Your representatives will be very glad to receive suggestions or instructions to take with them to the various sub-committees on which they

are working. The work is very comprehensive, and your sub-committee wishes to feel that it has the co-operation of all the members of this Association, so that when conclusions are reached and are submitted to you for adoption and are finally accepted that they will be recognized as having the endorsement of the entire membership of the American Railway Engineering Association.

Mr. Harwood:—The Committee has three recommendations which appear on page 618. We move the adoption of recommendation 1 of the Committee.

(The motion was carried.)

The President:—In recommendation 3, the Committee requests the convention to state what subjects in addition to those now being considered should be taken under consideration.

Mr. E. B. Temple (Pennsylvania Railroad):—I suggest that the Committee look into the matter of vertical clearances, as to where trainmen can remain on top of cars and where they cannot. There was a ruling passed by the New York State Public Service Commission where a height of 22 ft. above the rail was provided for. We are about to electrify our lines in Philadelphia and will probably adopt a height of 22 ft. Mr. Gibbs is on this Committee and undoubtedly helped prepare the diagrams submitted in the report. It is stated that 24 ft. is the minimum height of the contact wire that should be adopted in case the trainmen remain on tops of the cars with lanterns. The advice of this Association as to the proper height of contact wire is important and may affect rulings of other State Commissions. It makes a difference in heavy built up lines in suburban territory, with overhead bridges. If you make it 24 ft. and work down to these bridges, it means that we do not get the full 24 ft. for probably over 50 per cent. of the suburban territory.

Mr. Katte:—The first four diagrams were prepared by a sub-committee, of which Mr. Gibbs was the Chairman, and Mr. Murray, of the New Haven, a member. Had there been any such law enacted, Mr. Murray would have been cognizant of it and not allowed the diagrams to go through if they conflicted with it. Mr. Murray is primarily responsible for the first four diagrams.

Mr. J. C. Mock (Michigan Central):—Do I understand that the approval carries with it the approval of No. 5 diagram for publication in the Manual?

Mr. Harwood:—This is a minimum diagram and it covers that as a minimum.

Mr. Mock:—We have an installation where a great deal of the overhead in the shed itself is placed at the side to avoid smoke ducts, and I believe we will have trouble in maintaining a minimum distance of 15 ft. 3 in. for this overhead rail. We would have to make the installation about 15 ft. to allow for a clearance at the bottom of the smoke ducts. The third-rail shoe or pantagraph is about the middle. I should like to

have this diagram checked for the conditions we are up against.

Mr. Harwood:—I think Mr. Mock has some of the special c ditions some of the other roads have. On the New York Central had some special conditions where we had to trim the clearances to the third rail and shoe through, but we would not recommend that desirable in new construction, which these diagrams cover.

Mr. Mock:—The construction to which I refer is new.

Mr. C. E. Lindsay (New York Central & Hudson River):—How off the center of the line is the smoke duct?

Mr. Mock:—About 2 ft. 10 in., 6 in. from the outer edge of smoke duct concreted.

Mr. Katte:—The standard is for overhead rail on the center li of the track. When you come to the side you have a special constructi to which this standard would not apply.

The President:—The development of electric traction has been rapid during the past fifteen years that the work of this Committee not only of the greatest importance to-day, but the future work will be fully important, and the work done by the Committee so far is of t very greatest value. I am sure that the Association heartily thanks t Committee for its labors.

DISCUSSION ON WOOD PRESERVATION.

(For Report, see pp. 625-682.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOOD PRESERVATION.

W. M. CAMP.
J. L. CAMPBELL.
S. R. CHURCH.
G. B. SHIPLEY.
E. A. STERLING.
EARL STIMSON.
DR. H. VON SCHRENK.

The President:—The discussion on the report on Wood Preservation will be opened by the Chairman, Mr. Earl Stimson.

Mr. Earl Stimson (Baltimore & Ohio):—The Committee was directed to report on four subjects, as given on page 625.

The investigations of the merits as a preservative of oil from water gas tar were carried on this year in continuation of those carried on in previous years. Owing to its rather limited use and the rather meager data as to the results of this use, the Committee reports that it is not in position at this time to recommend the use of oil from water gas tar as a wood preservative. The second subject of the first instruction, namely, the use of refined coal tar in creosote oil, was investigated quite exhaustively by the Committee. This is the most important subject that the Committee had for consideration this year.

The Committee feels that the results of its investigations to date do not warrant a definite recommendation as to the use of coal tar creosote mixture, particularly with respect to its merits as a preservative. However, owing to the fact that the mixture is quite extensively used, the Committee feels that this use is entitled to recognition to a certain extent. This recognition takes the form of a definite recommendation, namely, that wherever possible only grade 1 coal tar creosote be used, and that under no circumstances should coal tar be added to creosote of this grade. With reference to grades 2 and 3, whenever it is found advisable by any railroad company to use coal tar in mixture with these grades, that certain precautions be followed. These precautions are given on page 627 and are six in number. These precautions are supported by a very able and comprehensive paper by Dr. von Schrenk and his associate, Mr. Kammerer, which is published in Appendix A to this report. It was the intention of the Committee to offer these six precautions for the approval of the Association and for publication in the Manual. However, since our report was published, certain information has been brought to light which changes our attitude in respect to offering these precautions for publication in the Manual. The question that arose in the minds of the Committee was whether or not it would be better to have these precautions offered as information, and accepted

as such, as in a measure they are preliminary and will be follow
some time in the future by a definite specification for the mixture.

The paper by Dr. von Schrenk gives results of laboratory tests wh
fully support the precautions offered, and since the Committee report
been published there has been offered by Mr. S. R. Church, of the Barr
Manufacturing Company, a report of tests from actual practice at
treating plant, giving the comparative results of use of the straig
creosote oil and the mixture. Mr. Church is present, and by way
discussion, the Committee, with the approval of the convention, will c
upon Mr. Church to give an outline of these tests. If it is your des
he is willing to offer same as information to be published.

Mr. S. R. Church (Barrett Manufacturing Company) :—Mr. Pre
dent and gentlemen, in briefly outlining the results of these tests
want first to take the opportunity of congratulating the Committee
the interesting and valuable information which is presented in su
logical and concise form in Appendix A by Dr. von Schrenk and
Kammerer. This is really the first time any full information on the s
ject has been made public and I know it will be a great deal of satisf
tion to the producers as well as to the consumers to have such inform
tion available.

The results reported in this Appendix are supported by informat
obtained in a series of plant operations in December, 1913, at the plant
the Pittsburgh Wood Preserving Company.

I submit herewith, for the information of the Association, and subj
to the approval of your Committee, a report of this series of tests.

(Mr. Church then briefly summarized the conclusions reached a
result of these tests. The full text of the report follows):

REPORT OF OIL TESTS MADE DECEMBER, 1913, AT THE PLANT OF THE PITTSBU
WOOD PRESERVING COMPANY.

The tests described herein were undertaken with the object of
curing information as to the practicability of treating various kinds
wood with creosote oil containing a substantial amount of filtered c
tar. Tests were undertaken jointly by the Barrett Manufacturing Co
pany and the Pittsburgh Wood Preserving Company, at the plant of
latter at Broadford Junction, near Connellsville, Pa. The work was c
ried out under the observation and direction of J. L. Conway, Super
tendent, P. W. P. Co.; W. J. Smith, Inspector, P. & L. E. R. R.;
Kuckuck, representative of the Rueping process; L. B. Shipley, rep
sentative of the Barrett Mfg. Co.

The woods treated were beech, birch, maple and gum grouped
gether; red oak, pine and chestnut treated separately. In all cases
cept the chestnut, one full cylinder treatment was made by the ordin
full-cell process, and another by the Rueping process. With chestn
only the latter process was used.

Throughout these runs the effort was made to obtain the same
absorption with each of the oils for the same process, namely, to ret
6 lbs. per cu. ft. by the Rueping and 8 lbs. per cu. ft. by the full-c
An exception was made in the case of the chestnut, endeavoring to ret
but 4 lbs. per cu. ft. by the Rueping process; the only variables, therefo
were the temperature of the oil and the time of operation.

The oils used were:

(1) Ordinary coal-tar creosote oil of No. 2, A. R. E. Assn. grade.

(2) Special oil containing filtered coal tar, prepared to meet the following specification:

The oil shall be a pure coal-tar product, containing no crude tar.
Water shall not exceed 2 per cent.
Specific gravity at 38 degrees C., 1.06 to 1.10.
Insoluble in hot benzol, not over 2 per cent.
Distillation by standard A. R. E. A. method:

Not more than 1 per cent. at 170 degrees C.;
Not more than 5 per cent. at 210 degrees C.;
Not more than 30 per cent. at 235 degrees C.;
Not less than 40 nor more than 60 per cent. at 300 degrees C.;
Not less than 60 per cent. at 355 degrees C.

Viscosity at 100 degrees C., not more than 25 seconds for 100 cc.

Oil No. 2 was especially made for these tests by the Barrett Manufacturing Company, and sufficient oil for the tests was shipped to the Pittsburgh Wood Preserving Company's plant in tank cars. It was carefully stored in a separate storage tank and analysis made before and after each treatment to determine that no accidental admixture of this oil with other oil had occurred.

Tests of Oils—The following are average analyses of the two oils used in the tests:

	No. 1 Regular Oil	No. 2 Special Oil
Specific gravity at 38 degrees C.	1.049	1.078
Water, per cent	0.30	0.30
Free carbon, per cent.	0.31	1.00
Viscosity (100 cc. (Engler):		
At 60 degrees C., seconds	25.5	28.6
At 100 degrees C., seconds	23.8	24.4
Distillation (A. R. E. A. method):		
Total to 170 degrees C., per cent	0.0	0.0
Total to 200 degrees C., per cent	1.7	1.5
Total to 210 degrees C., per cent	4.8	4.3
Total to 235 degrees C., per cent	37.8	28.7
Total to 270 degrees C., per cent	62.9	49.5
Total to 315 degrees C., per cent	76.3	59.4
Total to 355 degrees C., per cent	91.8	73.2

Method of Operation.—(See plan.) Sufficient oil for six charges was pumped from the storage tanks and thoroughly mixed in the underground tank. The oil was then pumped in the overhead weighing tanks and heated by steam coils to the desired temperature, and its weight accurately taken.

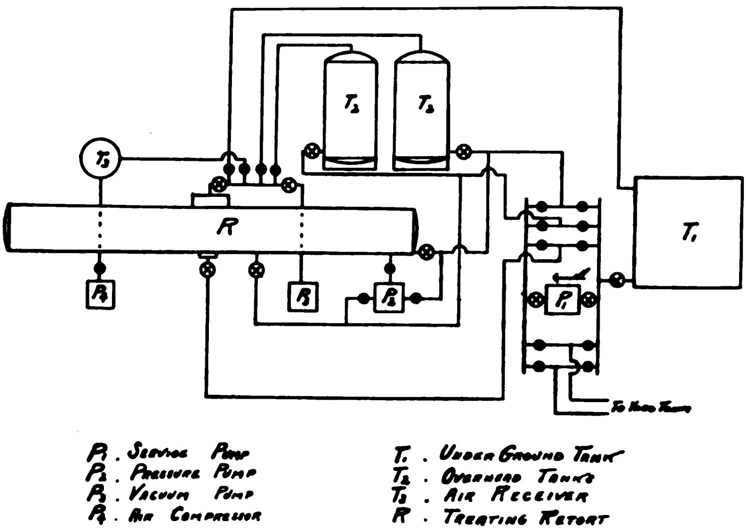
After the wood received its preliminary treatment, the oil was run into the treating retort and the weight used noted. The pressure pump was started immediately, and the weight of oil forced into the wood observed every fifteen minutes, until the desired gross absorption was obtained, upon which the pressure pump was stopped. The oil was dropped to the underground tank, and together with the oil later recovered by vacuum, was repumped to the overheads and reweighed. The loss in weight in the overhead tanks is the net absorption by the ties. The track scale weights of the charge before and after treatment were taken and their difference considered as the official figures for net absorption. Count of ties in each charge was taken and the absorption per cubic foot figured from a volume of 3.8 cu. ft. per tie, this having been frequently checked up.

Fifteen minute readings were taken of pressure, temperature and weight of oil forced into the ties. These readings are recorded on charts 1, 2, 3 and 4. A summary of the working operation of each charge is given in Table A.

(1) Adaptability for Use at Treating Plant.—Throughout this series of tests, the Special Oil was handled equally as readily and as easily as was the regular oil. The pumps exhibited no marked differences with either oil, and pumped them with equal rapidity. Since the working temperature for the Special Oil is somewhat higher (by approximately 20 degrees Fahrenheit) than for the regular oil, slight alteration in the heating coils may, under certain conditions, be required.

The test charges throughout came from the retort clean and dry, without any dripping. Slight differences were noted only between the Rueping and full-cell treatments, but not between the oils.

(2) Absorption and Retention by the Woods.—Reference to the absorption curves shows a slight advantage for the Special Oil in the time required for treatment by the Rueping process; in other particulars the two oils show practically no differences in absorption and retention,



other than are usually met with in general operation practice by either Rueping or full-cell treatment.

(3) Penetration into the Woods.—This is illustrated by photographs. Tie specimens of each of the woods were included in each test charge. These were arranged as follows: One tie was quartered, and a quarter placed in each test charge. Four ties were sawed in half, and two halves placed in each test charge, so placing that matched half ties would be in charges with the Rueping process for each of the oils, with the full-cell process for each of the oils, and also with the same oil in both the Rueping and full-cell process. In addition to these quarter and half ties, a whole tie was also included and weighed before and after treatment. The ties were cross-sectioned—the half ties under the rail plate and the whole and quarter ties at their middle, and these sections photographed immediately after sawing.

Each species of wood (except chestnut) is represented by two pictures, one of which shows the section of the whole ties and of the

TABLE A.

	Beech	Birch,	Maple & Gum		Red Oak				Pine				Chestnut	
	Rueping Full Cell				Rueping Full Cell				Rueping Full Cell				Rueping	
	Regular Oil	Special Oil	Regular Oil	Special Oil	Regular Oil	Special Oil	Regular Oil	Special Oil	Regular Oil	Special Oil	Regular Oil	Special Oil	Regular Oil	Special Oil
Test charge number	1	7	4	10	2	8	5	11	3	9	6	12	Extra 1	Extra 2
Plant charge number	2177	2183	2180	2186	2178	2184	2181	2187	2179	2185	2182	2188	2174	2190
Number of ties in charge	417	456	414	436	405	415	466	412	399	403	390	398	403½	388
Seasoning (months cut)	12	12	9	12	14	14	12	12	8	10	8	10	10	11
Initial air pressure, lbs.	65	60			60	60			75	75			75	75
Time of air pressure, minutes	40	40			40	35			50	45			40	40
Initial vacuum, inches			24	24			23	23			26	26		
Time of vacuum, minutes			60	60			55	60			55	60		
Oil pressure, lbs.	175	175	140	120	175	180	130	130	160	160	100	100	145	165
Time of oil pressure, hrs.	4:25	2:15	1	1	3	3:15	1:30	1:30	2:45	2:15	1	1	3	2:15
Oil temperature, degrees F.	190	205	185	205	180	205	190	195	190	210	182	200	190	190
Final vacuum, inches	23	23	24	24	23	23	20	23	24	24	24½	24½	23	23
Time of final vacuum, minutes	75	60	60	60	30	60	30	60	60	60	60	60	60	60
Overhead tank measurements by weight:														
Oil pumped into ties, lbs. cu. ft.	8.6	11.6	7.12	7.66	10.4	8.56	4.97	5.74	10.35	10.45	11.15	10.47	6.83	6.92
Oil retained by ties, lbs. cu. ft.	5.43	6.68	10.12	10.2	5.31	5.31	4.82	7.23	6.25	5.82	13.14	11.48	4.10	4.04
Track scale weight:														
Oil retained by ties, lbs. cu. ft.	5.42	6.59	9.89	10.17	5.06	5.21	5.72	7.02	6.00	5.65	12.88	11.41	4.02	3.82

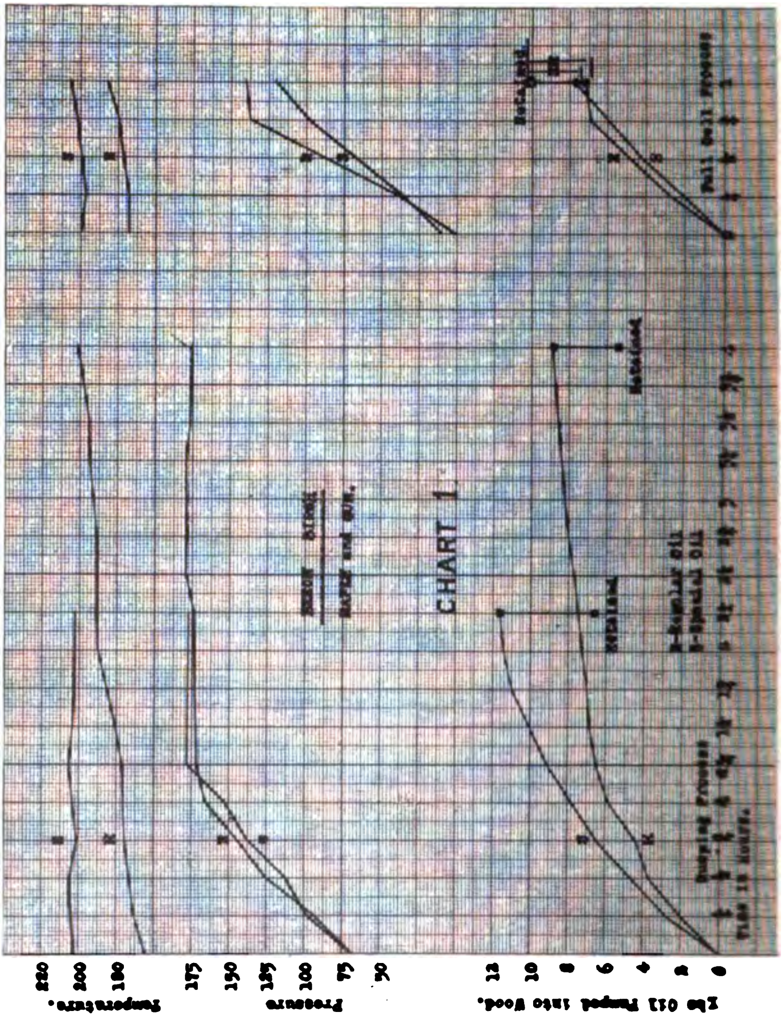


CHART 1
Temperature.
220
200
180
Pressure
175
150
125
100
75
50
Lbs Oil Pumped into Wood.
12
10
8
6
4
2
0
R-Regular Oil
S-Special Oil
Retained
Pumping Process
Full Cell Process

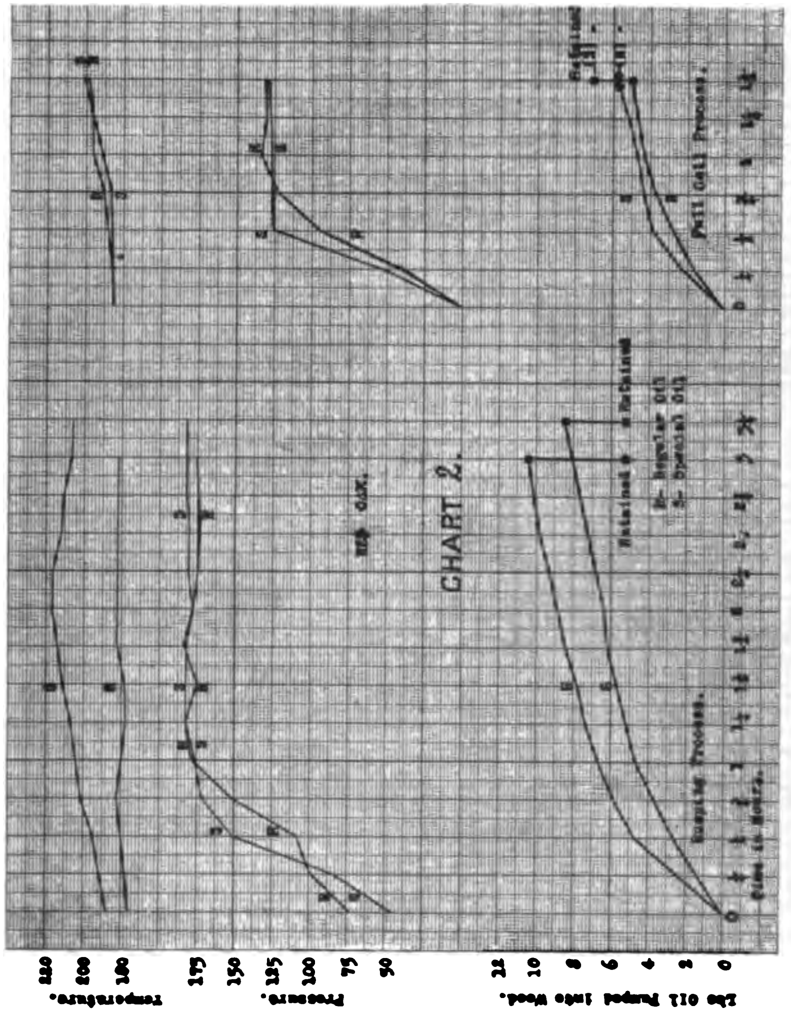


CHART 2.
Temperature.
Pressure.
Lbs Oil Pumped into Wood.
Time in Hours.
Rueping Process.
Full Cell Process.
R- Regular Oil
S- Special Oil

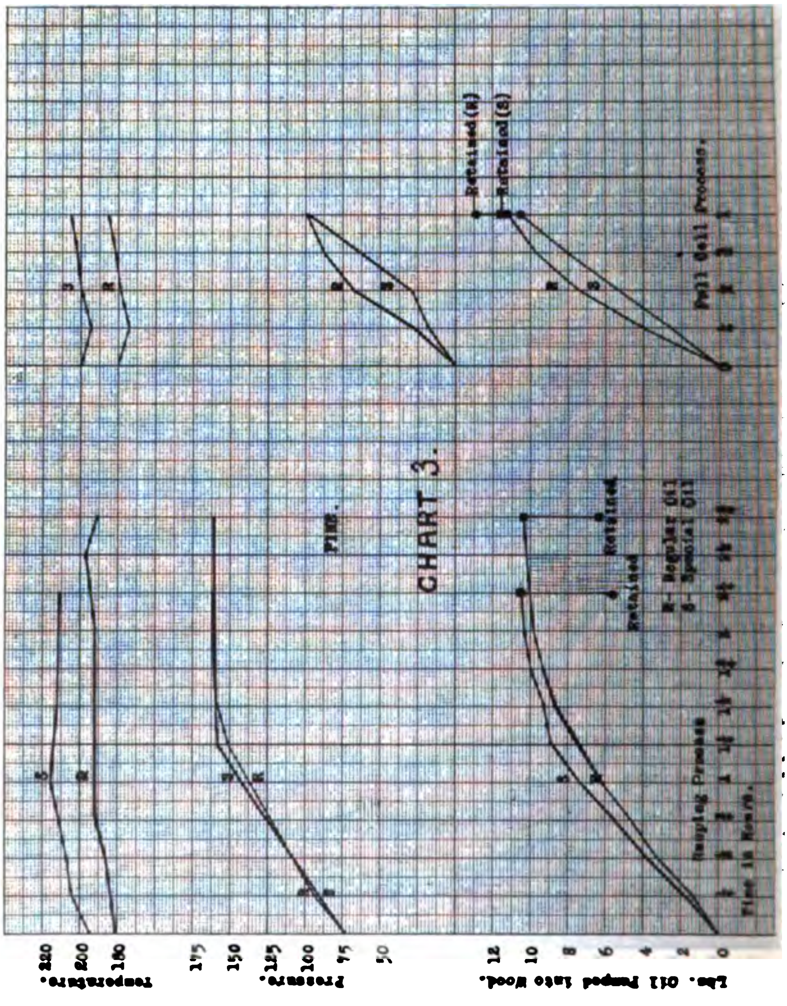


CHART 3.
PINE.
Temperature.
Pressure.
Lbs. Oil Pumped into Wood.
Retained
R- Regular Oil
S- Special Oil
Full Cell Process.
Rueping Process
Time in Hours.

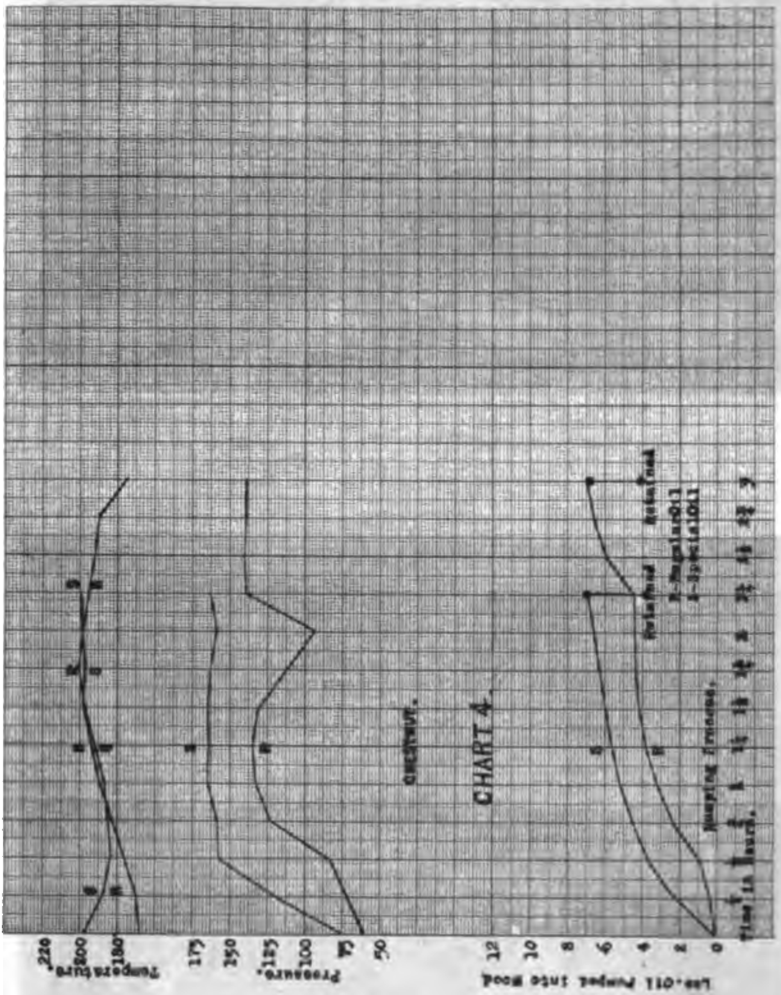
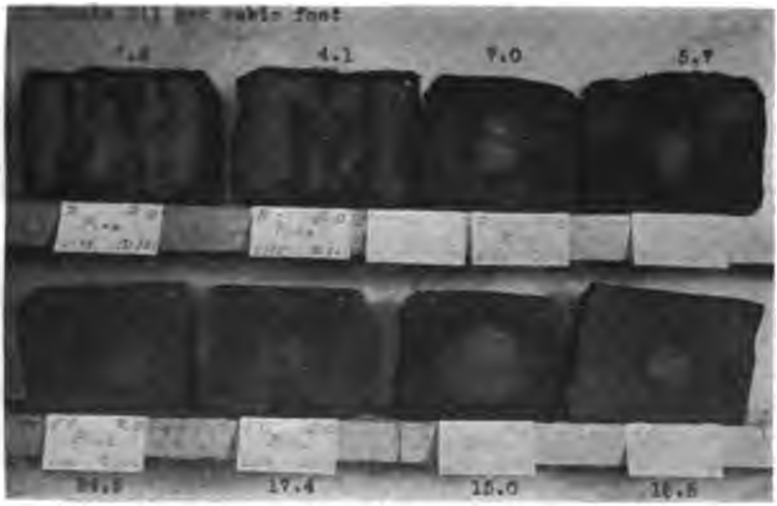


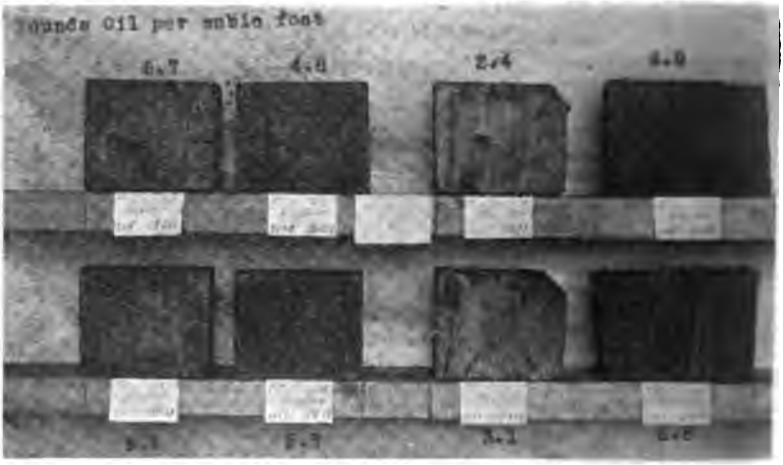
CHART 4.
Temperature.
Pressure.
Lbs. Oil Pumped into Wood


Pounds Oil per cubic foot
3.3
2.9
6.4
4.7


Pounds Oil per cubic foot
4.6


4.1
17.4


Pounds Oil per cubic foot
4.0
7.2


Pounds Oil per cubic foot
2.4


4.8
4.7

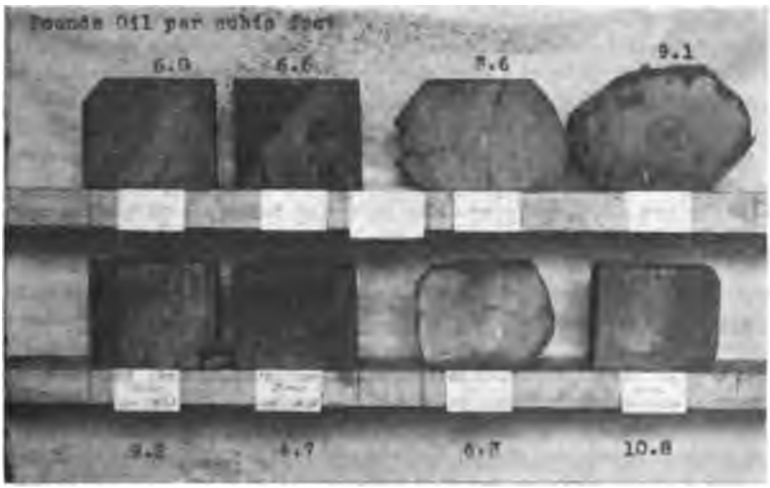

Pounds Oil per cubic foot
7.2
7.8
8.6
7.0


Pounds Oil per cubic foot
7.4
8.6


Pounds Oil per cubic foot
5.4
9.0


Pounds Oil per cubic foot
10.6


4.7
10.4


Pounds Oil per cubic foot
6.6
9.1
10.8

matched quarter ties; the other picture shows the sections of the matched half ties. In each picture the Rueping process (R) occupies the top shelf, and the full-cell (F. C.) the lower shelf. The oils alternate on the same shelf, first regular oil (R. O.) and then special oil (S. O.). On the card beneath each section is the charge number and the tie number. Whole tie numbers are preceded by a circle; half ties by a halved circle and quarter ties by a quartered circle. The middle number of each half tie shows the matched ties. Thus, for beech in the picture of matched half ties, *121* and *123* are the same ties treated by the Rueping process, with regular and special oil, respectively; and *111* and *112* are the same tie treated with regular oil by the Rueping and full-cell process, respectively. The chestnut ties were treated by the Rueping process only.

CONCLUSIONS.—The results obtained from these experimental runs show that the special oil containing oil derived from the filtration of coal tar, in accordance with the specifications given herewith, meets satisfactorily the conditions essential for proper treatment of cross-ties. This applies specifically to the case of handling in the process, and the absorption, retention and penetration into seven kinds of wood.

It was also noted that the surface of ties treated with the special oil was fully as dry and clean as those treated with the regular oil.

The President:—We will take up the conclusions on page 632, item by item, and discussion will follow.

Mr. Stimson:—It is the sense of the Committee that this be offered for insertion in the Manual, and I move that No. 1 be adopted by the Association and inserted in the Manual.

Mr. J. L. Campbell (El Paso & Southwestern):—As a practical proposition in case of scarcity of creosote, there is a question in my mind about the advisability of adopting that conclusion as it stands. It seems to me that if it were necessary to adulterate for any reason—scarcity of creosote being one—we could better afford to adulterate first-class creosote than an inferior grade. I would rather add a percentage of coal tar to No. 1 than to No. 2 or No. 3 creosote on the assumption that there is still a question about the result of the addition of coal tar.

Dr. H. von Schrenk:—Referring to Mr. Campbell's suggestion, I would like to point out on behalf of the Committee that we have taken a rather strong stand with reference to the term adulteration as applied to the addition of coal tar to the creosote oil. In view of the fact that the coal tar is the matrix or mother liquor from which coal oil is distilled, the addition appears to us to be in the nature of an addition of a similar product, rather than the sense in which that word is ordinarily used. As to Mr. Campbell's suggestion, this subject was brought up in the Committee meeting and aroused a great deal of discussion and it was suggested by a number of the Committee that we were taking a rather insistent attitude for the reason specified. Our chief reason, however, for recommending this rule was that there seems to be very little doubt as to the very strong and efficient preservative value of our No. 1 standard. It is the creosote oil which has given the longest length of life records both in this country and abroad, and we feel that any addition to it, while it might to a certain extent increase the permanency of such oil in the wood, would be in a sense changing its very character, and we did not

feel that we were warranted in recommending the addition of coal tar to No. 1 oil. After all the addition of refined coal tar to No 2 or No. 3 oil, was making the best of the situation, it being forced on us due to the lack of No. 1 oil.

Mr. W. M. Camp (Railway Review):—I am not entirely clear about this matter. As I understand it, the Committee is not in the position of recommending that coal tar be added to creosote. Am I correct about that?

Mr. Stimson:—Yes, sir.

Mr. Camp:—Then these conclusions mean that if one does do it, he should do it according to this formula; but the Committee does not recommend adding coal tar to creosote of good quality.

Mr. Stimson:—That is explained in the body of the report, on page 627.

Mr. Camp:—I fear that the adoption of these conclusions may be misleading; that they may used to support a claim that this Association does recommend adulterating creosote. It is adulteration, pure and simple. The manufacturer takes coal tar and distils it, and at a certain temperature there goes over what is called creosote, of a certain grade. Five or six years ago a good deal of attention was paid in this Association to the chemical composition of creosote, and a good deal of emphasis was placed on the importance of having a good article, according to the best knowledge which had been obtained in experimenting with creosote. Now it is proposed, by some, after they take coal tar and distil creosote out of it, to mix some of the raw product with it again. Call it refined coal tar if you wish.

The ground on which the Committee excuses the use of this practice is that we cannot get a sufficient supply of creosote of first quality. The ground is therefore one of expediency. I think it is letting down the bars to the use of an inferior grade of antiseptic which will still go under the name of "creosote." As I have always understood it, creosote is the best material to be used in treating ties. Comparisons have been made between zinc chloride and creosote, and, with zinc chloride and creosote mixed. It has always been understood by men who have discussed this subject in an unbiased manner that creosote was the most efficient material for treating ties, referring, of course, to the use of the heavier oils. I am afraid that if a method of treating ties by an adulterated article is approved, that such may be taken as approval of the inferior article; and who can say that the mixture of tar with the lighter oils really accomplishes the purpose sought? I have observed ties treated with such mixtures where it appeared that all of the tar remained on the outside of the timber. I am not, however, able to say whether or not such precautions as are laid down by this Committee were followed in the treatment of those ties.

Mr. Stimson:—I regret that the gentleman, after our explanation, persists in referring to it as an adulteration. The Committee's position is quite clearly set forth in the text of the report. We do not recommend, but we recognize, a prevalent practice. The question is whether we want to stand out for a practice that is largely ignored, or whether we want to frame our recommendations to meet working conditions.

Mr. E. A. Sterling (Consulting Forester):—I think the Committee as a whole will agree with Mr. Camp, that creosote was and is the desirable preservative. It is also true that certain commercial conditions have arisen in connection with the use of creosote; while the fact that it is the best preservative of that kind has naturally led to rapidly increased use until the point has been reached where not only is the price higher, but there is an actual difficulty in getting the required supplies. These conditions have no doubt been largely responsible for the use of coal tar, in order to increase the quantity available and still be able to use a coal tar product. We cannot get away from the recognition of this practice, and from any evidence now in sight conditions are not going to improve as to the quantity and price of creosote. Personally I think it is the feeling of the Committee that we should recognize the existence of this commercial condition. Having recognized a commercial condition it remains to apply the best technical measures possible for the protection of the people who have to use this mixture or desire to use it. The question of adulteration has been covered by Dr. von Schrenck and there is no use going over it again, but we do not feel that coal tar is an adulteration in the usual sense of that word. By following the precautions suggested here, as based on the experiments made and results shown by Dr. von Schrenk and other investigators, very reliable results can be obtained, with the proper sort of mixture, properly applied.

Mr. Camp:—If there is such a remarkable shortage of creosote and not more than 30 per cent. of tar is to be mixed with it, the creosote will not go so much farther after all.

Dr. von Schrenk:—One of the chief reasons for the commercial use that Mr. Sterling has referred to is that the use of the coal tar makes a grade of creosote oil available for the treatment of ties which otherwise could not be used at all. So it is not simply a question of increasing the coal tar volume. A commercial condition has existed, and we all recognize that. It has existed in a sort of sub-rosa fashion. We all have known a good many years that creosote oil was being sold under our No. 1 specification, which consisted of No. 2 or No. 3 oils, to which coal tar had been added. The chief purpose of the Committee in making these recommendations is to state openly that such a practice is in existence. As I have attempted to indicate in the Appendix, about 40 per cent. of the creosote oil used to-day in the United States is a combination of creosote oil and coal tar. With the increased price of No. 1 oil and its increasing scarcity we are confronted by the alternative question of either using a cheaper oil, in larger quantities and paying more for it, or using a cheap oil with a slight addition of refined coal tar, which we otherwise could not use. The whole problem is simply one of stating publicly that such a thing is being done, so that everybody may know it. As the chairman has indicated, these are preliminary suggestions looking toward an ultimate specification which shall say openly and above board to any consumer who wishes to buy it, "Here is No. 1 oil, costing so much. Here is No. 2; here is No. 3, with coal tar, costing so much. We leave it to you to take your choice." Probably in a year or two the Committee will be in a position to say something specific as to the desirability of No. 1 oil or the oil with the coal tar added to it. We do not feel that we can take that responsibility as yet.

Mr. Camp:—Does the Committee state anywhere that it does not consider the mixture of coal tar and creosote to be the best practice?

Mr. Stimson:—Yes, on page 627. "It is, however, the opinion of the Committee that coal tar should not be added to high grade creosote."

Mr. Camp:—You say, wherever possible, only Grade 1 coal tar creosote should be used. That saves the situation, for in the same sentence the Committee's recommendation forbids the mixture of coal tar with this grade of creosote. The Committee thus intends that in the creosoting business there shall be one article that shall be first class and that it shall not be adulterated.

Mr. Stimson:—Yes, we have always stood out for that. "And under no circumstances should coal tar be added to creosote of this grade." That is the recommendation that is now before the convention.

Dr. von Schrenk:—Some years ago this Committee brought in three specifications for creosote oil, No. 1, No. 2 and No. 3, and at that time Mr. L. C. Fritch asked a very pertinent question of the Committee, which we had to admit we could not answer. He said, "You bring in three specifications. You give us nothing to indicate when we shall use No. 1,

No. 2 and No. 3," and we had to give the rather indefinite answer that No. 2 and No. 3 were available oils and we recommended in general that we use larger quantities of No. 2 and No. 3. That was based upon our conviction that the reason for using No. 2 and No. 3 was that they evaporated from the wood quicker than No. 1. At the present time we say, "When you can buy No. 1 oil use it, and do not add any coal tar to it. When you cannot get No. 1, if you decide to use No. 2 or No. 3, use it either in larger quantities, according to our recommendation two or three years ago, or if you decide you are going to put coal tar into No. 2 or No. 3, be careful that you follow some of these precautions."

Mr. Campbell:—This conclusion, when adopted by this Association, should be so worded that if a railroad decided that it was best for it to dilute No. 1 creosote such decision should not be contrary to the adopted recommendations of this Association. I do not consider that the dilution of No. 1 creosote has anything to do with the specification for that grade, because as soon as you dilute any grade of oil you have something different and it does not then come under the specification for the original. I see no inconsistency in diluting No. 1 as compared with No. 2 or No. 3. On account of the general scarcity of creosote I do not believe any unnecessary restrictions should be placed on the use of coal tar. The report of this Committee holds out some hope to the railroads for relief under the existing scarcity of oil. If the railroad with which I am connected becomes convinced that coal tar can be added to creosote and a proper preservative secured, thereby increasing the quantity so that more ties can be treated, I think that railroad may be willing to dilute its creosote. Under such circumstances we would like to do so without acting contrary to the recommendations of this Association.

Mr. G. B. Shipley (Consulting Engineer):—I know it to be a fact that creosote, during the last nine months, has been very scarce. Heretofore the majority of the large railroads have insisted that we use all No. 1 creosote. This summer at least eight plants were shut down because they could not get No. 1, or German creosote. About 60 per cent. of the creosote used in the United States is imported from Germany, and the importers find it practically impossible to secure enough creosote to go around. This means that the Association should have three or four standard specifications. Another thing that interferes with the use of No. 1 grade creosote is the fact that creosote has increased in price 2½ cents a gallon f. o. b. coast points within the last two years. If you add freight, that means you will pay 11 or 12 cents for creosote, which is almost prohibitive. Whereas, if we are permitted to use several grades, it will be possible to secure additional creosote from domestic factories.

Dr. von Schrenk:—I do not personally see any reason why anybody that wants to add refined coal tar to No. 1 oil should not do so. He thereby increases the volume of his oil 10 or 20 per cent.; but at the same time the Committee understands that the reason why refined coal tar is added is not chiefly for the purpose of increasing the volume of available oil. The chief purpose of those who are adding coal tar to the

inferior grades of creosote is to realize the permanency of the oil after it is injected into the wood. By comparison we have used No. 1 creosote oil as the standard on evaporative properties because by experience we have found that we get good and sufficient service from the standpoint of time out of the chemical composition of No. 1 oil. The chief reason why coal tar is added where it is done to creosote No. 2 and No. 3, is to bring oils of the grade of Nos. 2 and 3 up to that standard as far as the permanency is concerned. If it incidentally increases the oil supply a small percentage by the addition of the coal tar used and also by the increased oil supply of No. 2 and No. 3, that is an incidental matter and I can see no reason why coal tar should not be added to No. 1. The reason that this Committee stands out strongly in its recommendations is to obviate what Mr. Camp objects to, that we want it to be strictly understood that we are standing squarely on the proposition that where you can use No. 1 creosote oil, do so, without the addition of coal tar.

Mr. Campbell:—The cost of creosote is high. It seems to me that there is a probability that we can secure the preservative results that we require for ties by the addition of coal tar to creosote and thereby reduce the cost per gallon of the preservative. If that is true, I think one reason for the addition of coal tar would be the reduction in cost of the oil and consequently a reduction in cost of treatment per tie and an increase in the number treated.

Mr. Stimson:—The Committee wishes it distinctly understood that it does not recommend the addition of coal tar to the No. 1 grade. We want to preserve the No. 1 grade as the high standard. We do not recommend changing our standard, and we wish the recommendation to go before the convention as it stands.

(Conclusion 1 was thereupon adopted.)

Mr. Stimson:—In conclusion 2 we want to strike out the words "and poorer" after "American Railway Engineering Association," and change precaution (b) to read, "That the coal tar be added to the creosote under the direct supervision of the railway company, and preferably at the plant."

(Mr. Stimson then read conclusion 2 (a, b, c, d, e).

Mr. Stimson:—I move that these precautions as read be received by the Association as information.

(The motion carried.)

Mr. Stimson:—I would like to call attention to the fact that the changes just noted in these precautions as printed on page 632 also apply to the text of the report on page 627. Also on page 629, fourth line, last paragraph, third word should be "source," instead of "course." And on page 679, second line, next to last paragraph, third word should be "coal," instead of "coal tar."

(Mr. Stimson then read the second and third subjects assigned the Committee.

Mr. Stimson:—No conference was held with the Committee on Grading of Lumber. The subject of grouping timber is one that is worked out

locally at each plant, and other than the fundamental principles, already adopted by the Association, the Committee is unable to go into further detail and recommends that the investigation of this subject be dropped. The fourth subject is report on methods of accurately determining the absorption of creosote oil. A description of the three systems in general use for determining the absorption of preservatives is given in the report, followed by a discussion.

We recommend that the investigation of this subject be continued next year.

Under the heading of "Conclusions," the Committee presents two recommendations pertaining to the determination of absorption for adoption and insertion in the Manual, as given on page 632.

(On motion, the two conclusions were adopted.)

Mr. Stimson:—We have here the report of tests referred to by Mr. S. R. Church, and we would like to have this report accepted by the convention to be printed as information in the discussion of this report.

The President:—If there is no objection, the report will be printed.

Has the convention any subjects to suggest for the work of the Committee during the coming year? If not, the Committee is excused, with the thanks of the Association.

DISCUSSION ON GRADING OF LUMBER.

(For Report, see page 683.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON GRADING OF LUMBER.

Dr. Hermann von Schrenk.

The President:—The report of the Special Committee on the Grading of Lumber will be presented by the Chairman, Dr. von Schrenk.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—Owing to the nature of the subject assigned to us it involved frequent conferences with the various manufacturing organizations which produce various grades of lumber, and in view of the fact that their committees are somewhat ponderous and the deliberations were scattered over a considerable period of time, we found ourselves in a position of not being able to agree upon any set of specified rules this year. We, therefore, have nothing but a progress report to offer, with indications that next year the series of specifications we are drawing up for Northern woods, particularly hemlock and white pine, will have progressed sufficiently so that they can be presented.

We have spent a great deal of time and energy in persuading the various lumber manufacturing organizations of the desirability of adopting the standards promulgated by their associations and this Association. Your Committee is finding considerable difficulty, and we will admit discouragement, owing to the fact that we are constantly being met with the objection on the part of the producer of lumber for maintenance material, who state that there is no use in their conferring with us, because after they adopt the rules we propose there is not a single railroad company in the United States which ever buys a stick of lumber under the rules which we adopt. It is rather discouraging to have these rules adopted, and your Committee appeals to you to use your good offices to see those who are responsible for the purchase of lumber are at least advised of the fact that we have standard rules. Lumber is going up in cost. The specifying of abnormal sizes and abnormal grades always costs very much more money than the specifying of standard sizes and grades, and your Committee feels sure that by adhering to some of the standard sizes which this Association has hitherto adopted, particularly for heavy stringer timbers, like yellow pine and various classes of oak wood, that a considerable saving could be effected.

Next year we hope to present a complete series of rules, having been working on these for some time, which will probably close up the work of this Committee.

The President:—Is there any discussion? The convention desires to thank the Committee for its labors and it is dismissed with the thanks of the Association.

DISCUSSION ON WATER SERVICE.

(For Report, see pp. 685-704.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WATER SERVICE.

J. L. CAMPBELL. A. F. DORLEY.

The President:—The next subject to be considered is that of the Committee on Water Service. It will be presented by the Chairman, Mr. A. F. Dorley.

Mr. A. F. Dorley (Missouri Pacific):—The report of the Committee on Water Service will be found in Bulletin 163, page 685.

(Mr. Dorley then outlined the report.)

I wish to call particular attention to the statement made on page 693, which illustrates the experience of a road in the Middle West on three divisions. Division "A" is equipped throughout with complete water softeners, that is, both lime and soda ash are used to remove both the carbonate and sulphates. On Division "B" partial treatment only is used, that is, soda ash only, and on Division "C" no water softeners are in use. In the table is given the apparent saving or loss in boiler repairs on Division "C" as compared with the other two divisions. You will notice quite a marked difference between Division "A" and Division "B," which illustrates the advantage of full treatment over partial treatment. The comparison between Division "C" with either Division "A" or Division "B," illustrates quite definitely that there is marked advantage in water purification.

The Committee in submitting these figures has made every effort to be conservative. We feel that in presenting a thing of this kind with any degree of mathematical accuracy is about as difficult as it would be for an individual to try to calculate how much he would save in doctor's bills if he used pure water as compared with polluted water.

The Committee moves that the report on subject No. 2 be received as information.

(Motion carried.)

Mr. Dorley:—The third subject to be reported on by the Committee is "Recent developments in pumping machinery." This is a subject upon which a great deal of hard work has been done by the sub-committee but unfortunately it is not in shape for final submission. With the consent of the Board of Direction, the Committee will continue the study of this subject for another year.

In Appendix A will be found a report on "Corrosion Tests on Iron and Steel," by Mr. J. L. Campbell, Vice-Chairman of the Com-

mittee. These tests were conducted by him personally with the object to determine, if possible, the most suitable and most lasting material for steel water tanks.

Mr. J. L. Campbell (El Paso & Southwestern) :—I want to refer to one thing in the report of this Committee on page 686. In section (1) it says "Many of the benefits are of such an intangible nature as to be very difficult of mathematical expression." That refers to the results of the treatment of water. I happen to be impressed with that statement as to how much it may mean under certain conditions. As a result of the expenditure of a large sum of money on the road with which I am connected a very bad supply of water on one division was replaced with a supply of very good water. One of the marked benefits derived was what may be described as a great improvement in the *esprit de corps* of the organization. The water was so bad, engine failures so numerous and train service so demoralized that everybody on the division was discouraged. When the good water was secured and the traffic began to move properly, everybody was relieved and encouraged and the boys began to "hit the ball" cheerfully and regularly. These indeterminate values in such a case are unusually large, but they apply to a marked extent to this subject generally and it is a phase of the matter that is deserving of consideration. I venture the assertion that if any road which has a bad supply of water will introduce a thorough system of treatment, such road will derive large indeterminate values.

With reference to the corrosion tests which have been referred to by the Chairman, I have nothing particular to add to the report. Your attention is called to the remarkably small difference in the corrosive resistance of the various samples, notwithstanding some of them were of a specially pure iron and some of the steel was treated with copper. About all that can be said at the present time as far as these tests indicate is that there is little indication of any marked superiority in any of the metals. Evidently we have not yet found a panacea for the important corrosive question.

Recently I met Mr. Buck, of the American Tin Plate Company. I went over this matter with him and found that the results of these tests are in substantial agreement with what they have found under similar conditions. You will notice that these tests were in soil. None of them were in the air. We have so little rain in El Paso and the atmosphere normally is so dry that any kind of good metal exposed to the air only would last indefinitely. Consequently I did not undertake testing these metals by exposure in the atmosphere.

Mr. Buck says that their corrosion tests in soils are in harmony with the results here reported, but that they have found an advantage for the copper-bearing steel in exposure to the atmosphere only. I am not prepared to express an opinion on the latter.

In this report you will notice that samples Nos. 6 and 7 of the copper-bearing steel had no surface treatment prior to the beginning

of the tests. The copper oxidation on the surface of the samples was quite perceptible and was left as it came from the mills. There is indication that during the first three months this oxidation afforded some protection to the surface of the metal, but the corrosion of these samples at the end of six months compared with the other copper-bearing samples indicates that such initial protection, if any, had disappeared in six months.

The special iron shows a slight superiority in the exposure in the cooling water from the converters of the Copper Queen Consolidated Mining Company at Douglas, Arizona. This water has exceptionally high corrosive action on the steel water jackets of the converters. The advantage for the special iron is small and we can say in a general way that there is remarkably small difference in the corrosive resistance of all the samples. Visual inspection reveals the fact that all of them are failing rapidly with the exception of those in certain alkali soils.

The tests are being continued during the coming year.

The President:—Is there any further discussion on this report? If not, the Committee is excused with the thanks of the Association.

DISCUSSION ON BUILDINGS.

(For Report, see pp. 705-723.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BUILDINGS.

G. D. BROOKE.
CHAS. S. CHURCHILL.
MAURICE COBURN.
L. A. DOWNS.
M. A. LONG.
H. C. PHILLIPS.
R. C. SATTLEY.

The President:—The report on Buildings will be presented by the Chairman, Mr. Maurice Coburn.

Mr. Maurice Coburn (Vandalia Railroad):—The first thing attempted by the Committee this year has been a discussion on roofing, condensed from the report of the previous year. We were given permission last year to abstract the report for the Manual. We attempted to do this, but the results were unsatisfactory, and we therefore condensed the matter and summarized the important points. This information is necessarily brief and many important points are omitted; possibly in some cases the information presented is so incomplete that it may seem misleading, but we trust such will not be the case. One or two points may be slightly changed from what is now in the report, but they are comparatively unimportant.

I move that the report on Roofing be accepted and printed in the Manual.

(Motion carried.)

Mr. M. A. Long (Baltimore & Ohio):—I have been asked to present the part of the report dealing with "Principles Covering Designs of Inbound and Outbound Freight Houses."

The first paragraph should be revised to read as follows: "The following report on Freight House Design is presented for publication in the Manual. This report does not cover freight piers, and deals only with single-story freight houses where the mechanical handling of freight is not considered."

Also eliminate the line "This report does not cover freight piers" at the end of the section on Freight Houses, page 714.

Also add on page 711, middle of the page after "Important Terminals:" "Many roads are building cars that are lower than the maximum figures given above, and each road in deciding the height of platform above the top of rail should take into consideration the sizes of cars that predominate on its lines."

I move that the matter just read be accepted and approved for publication in the Manual.

(Motion carried.)

Mr. H. C. Phillips (Santa Fe):—I would ask if the Committee has any examples to cite, as to the freight floor sloping 1 in. in 8 ft. in the

direction of the trucking, or whether that is a theoretical consideration.

Mr. Long:—The Committee has only theoretical information.

Mr. Phillips:—The amount of slope seems so very small that it was doubtful to some of us whether we would not need the freight house floor level or sloped for drainage and abandon the slope in direction of the trucking consideration in most cases.

Mr. R. C. Sattley (Rock Island Lines):—Has the Committee considered the direction in which the plank in the freight house floor should be laid?

Mr. Coburn:—That matter was discussed last year; we are not going into the freight house floor question at this time.

Mr. G. D. Brooke (Baltimore & Ohio):—I am very much in favor of having this report published in the Manual, but it seems to me that it may be made more convenient by the use of marginal notes. In some cases one note could cover several paragraphs, but in looking for one specific subject now, the whole report will have to be read.

Mr. Coburn:—The Committee will accept that suggestion.

Mr. Chas. S. Churchill (Norfolk & Western):—On page 711 the clearance of the face of the platform or freight house is given as not less than 5 ft. 9 in. I think that is too close to the freight house, according to proper clearances and is contrary to the laws of several states.

Mr. Coburn:—In the matter of clearances, the Committee agrees that 5 ft. 9 in. is too close to the building. We had the section 5 ft. 9 in. for the platform, and then remembered we had stated in some cases it might be desirable to have a freight house without any platform, and we put that in. We say it should not be less than 5 ft. 9 in. It might be misleading, of course.

Mr. Churchill:—I suggest that you omit the words "freight house."

Mr. Long:—We communicated with various roads and obtained typical cross-sections of new freight houses, and we found some of them used dimensions less than 5 ft. 6 in. from center of track to face of platforms, and some of the freight houses were 5 ft. 8 in. from the center of track to face of house. I understand that the law in Ohio is 5 ft. 9 in. from center of track to face of platform.

Mr. Churchill:—My recollection is the Ohio law requires about 6 ft. minimum above the level of a freight house platform.

Mr. Long:—I suggest in line with Mr. Churchill's remarks that this section be amended to read 5 ft. 9 in. to the face of the platform and 6 ft. to the face of the freight house from the center of the track.

The President:—In its report the Committee presents a statement on shop floors.

Mr. Coburn:—The Committee feels that this part of the report is also rather incomplete. The same criticism applies to this part of our report that was made about one of the reports this morning in discussing asphalt. We speak about asphalt flooring and give a little information about building it, but say nothing about the material. It is an important subject, and we feel that this part of the report should be amplified con-

siderably. We think there should be more information about wood block floors. There are many chances for error in laying them and there should be more detailed information presented.

The Committee presents this report with the understanding that it is not complete, but that what has been presented should be printed in the Manual.

Mr. L. A. Downs (Illinois Central):—As the Committee states that the matter is incomplete, do we want to put it in the Manual until the final report is made? It has been against our policy to place partial reports in the Manual or any deductions we might make from the reports until they are completed.

Mr. Coburn:—The Committee believes that there is some information of value in what we have reported, and that as far as presented it was complete in itself. These subjects can be amplified without end. If the Association decides that this part of the report should not be placed in the Manual, we would not object.

Mr. Downs:—I would consider that a report of this kind should be received as information. I believe that matter of this nature should not be put into the Manual until it is completed.

I move as an amendment that this part of the report be received as information only.

(Motion carried.)

The President:—Are there any suggestions with respect to the work of this Committee for next year? If not, the Committee is excused with the thanks of the Association.

Mr. E. M. Rosher (Cuban Central Railways—by letter):—The Committee recommends the adoption of their report on Freight House Design in substitution for the conclusions already in the Manual.

It is not quite clear whether they intend to eliminate the latter half of the "Outbound Freight House Clause" (page 395), relating to a "freight house built at right angles to and at the back end of a series of tracks built in pairs with covered platforms between."

I would regret to see this omitted, as this class of freight house has undoubted advantages. On the other hand, further information from the Committee on the subject as to proportions and limiting size and conditions would be of considerable interest and value. Any further information as to the actual working in practice compared with the ordinary long inbound and outbound houses would be useful.

Mr. E. A. Frink (Seaboard Air Line—by letter):—Because of serving as teller at the recent convention, the writer was prevented from taking part in the discussion on the report of the Committee on Buildings. On page 709 of their report, in the third paragraph, under "Metal Roofing," they decry the use of metal shingles, so called, which the writer believes to be a mistake.

There is no doubt that steel or iron roofing, protected only by paint, is of very doubtful durability, and, moreover, requires frequent painting. When used in the form of shingles over sheathing, of necessity only one

surface can be repainted. But when properly galvanized, the painting except for appearance, is largely unnecessary, the shingle being durable without.

Plenty of evidence is available showing a life of 25 years or more for metal shingles, properly made and laid. But to obtain this service it is essential that the same care be used in inspecting and testing the material as is used with other permanent construction. Attached is a copy of a shingle specification that is in use on this road, which is submitted as a basis for investigation by this Association.

The requirements for a good metal shingle roof are as follows:

(1) The shingle must be redipped, that is, dipped after being formed. If the shingle is cut and stamped from pre-galvanized sheet metal, from two to four edges are raw and ungalvanized, the zinc coating is usually too thin, and the process of stamping and forming the lock is apt to crack or flake the zinc coating.

(2) The zinc coating must be heavy, because upon this coating depends the life of the shingle. A 30-gage metal, properly coated, will far outlast a 24-gage poorly coated.

(3) The zinc coating must be uniform, the reason for which is obvious.

(4) The roof pitch should preferably be not less than 6 in. to the foot, although slopes as low as 4 in. to the foot may be covered if sufficient care is taken.

(5) The roof should be covered under the shingle with a good rosin-sized building paper.

It is also better, though not essential, to use a shingle stamped into comparatively high relief; say not less than ½-in., as this makes a stiffer shingle, and a better looking roof. Shingles shaped like Spanish tile are obtainable, and make an artistic roof.

It is obvious that any of the pure irons may be used as bases. Believing, however, that the value of the shingle depends principally on the coating, the writer does not advise the use of the pure irons unless at practically the same cost.

It may be argued that a metal shingle roof cannot last longer than one of galvanized corrugated iron. But the cases are unlike. The zinc coating on the shingle is heavier, and the underside is protected by the roofing paper. Moreover, corrugated iron must necessarily have numerous holes punched in each sheet in order to fasten it in place, these holes being usually protected from the weather only by the head of the nail. bolt or rivet used as a fastening, each hole thus becoming a vantage point for the attack of rust, while the two-nail holes in each shingle are both under the lock of the next shingle, thus being entirely protected.

For a large proportion of railroad structures, 25 years of life may be called permanency. A due regard for changing conditions will lead the engineer who has at heart the true interest of his company in many cases to specify material having a life expectancy of 25 years, in preference to a higher-priced material having a longer life.

The writer requests that as part of this year's work, your Committee on Buildings be instructed to investigate this question thoroughly and prepare a specification for the manufacture and use of galvanized metal shingles.

The following are the Seaboard Air Line Company's standard specifications for metal slates and shingles:

"All metal slate or shingles wherever shown or specified will be Cortright's Victoria Shingles, or equal. They shall be about 10 in. wide by 14 in. long, made of best grade roofing plate, hot galvanized, carrying not less than 1 oz. of zinc per sq. ft. of surface of each side of shingles. The sheet steel or iron of which the shingles are made, shall not be thinner than No. 30 B. W. G. The complete shingle must weight at least 9¾ ozs. per sq. ft. of metal. The highest part of the formed up metal shall be at least ½-in. above the flat body of the shingle. Shingles shall be well formed, true to size and shape, with well-made locks. The zinc coating must be evenly distributed over all parts of the shingles and must be applied after the shingle is fully formed, and must not crack or flake off when the metal is bent double to a radius of ⅛-in.

"Metal slates or shingles must be laid over tongued and grooved sheathing surfaced one side, laid diagonally or parallel to the eaves of the building. Cover the entire roof over the sheathing with waterproof sheathing paper, free from tar or asphalt, weighing not less than 20 lbs. per sq., all laps to be at least 3 in. wide. Over this lay the metal slates in strict accordance with the manufacturer's specifications. All courses must be strictly parallel to the eave line, all joints between shingles vertical, and the joints in any course must come exactly at the center of the shingles in the next course above and below.

"Hips, valleys, ridges, gables, etc., must be finished with the proper fitting pieces as made for the purpose by the manufacturer of the shingles used and as may be shown or specified. All cutting and fitting of the regular shingles to fit at gables, hips, valleys, chimneys, etc., must be carefully and neatly done. Furnish and lay all necessary flashing of No. 26 galvanized sheet metal of sizes required or specified. All nails used to be balvanized steel wire nails 1 in. No. 13."

DISCUSSION ON RAIL.

(For Report, see pp. 151-381.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RAIL.

J. A. Atwood,	C. E. Lindsay,
J. L. Campbell,	R. Trimble,
W. H. Courtenay,	M. H. Wickhorst.

The President:—The report of the Rail Committee will be presented by Mr. J. A. Atwood, the Chairman.

Mr. J. A. Atwood (Pittsburgh & Lake Erie):—I would ask Mr. Trimble, chairman of the sub-committee on standard rail sections, to present the report on that subject.

Mr. R. Trimble (Pennsylvania Lines):—The Committee has been embarrassed a little by the instructions that it has received, and I think this Association ought to understand the position of the sub-committee that is working on the problem of sections.

Several years ago the American Railway Association evolved two sets of sections called series A and series B. Then the matter of studying these sections was referred to this Association and we were asked, if possible, to recommend one section for the use of railroads. When we come to collect information in regard to the comparative merit of these two sections, we find that we do not get very much information. There are only a few people who have gone to the trouble of making comparisons between these two sections, some have selected sections series A and said, "That is good enough, we are satisfied with that section." Others have selected series B and have said, "That section is good enough; we are satisfied with it." Because of that attitude we do not get any comparative information.

If three or four years ago a number of important railroads had selected pieces of test track and put both of these sections on that test track, we would then have some information which would be of value. There are a few roads that have gone to the trouble of putting in both of these sections, and the information that we have is somewhat conflicting, and that makes it difficult to draw any definite conclusions from what has been done.

We find in looking over the statistics in response to the inquiries sent out by the Committee that a great many of the roads which use the old A. S. C. E. section are entirely satisfied with that section and they do not want to make any change. They have not given the A. R. A. sections series A and B any consideration. They object to a change of standards. We assume these must be roads of comparatively light traffic, although there are some very important roads in that category.

We find that there is a disposition on the part of a great many roads not to make any change, and not to make any experiments until this

question of sections is settled, and if it is to be settled on the basis of the experiments that are now being conducted it will have to be settled from experiments made by a very few railroads.

We also find a tendency to develop new sections varying by the merest trifle from the sections now in existence. I think I voice the sentiment of the entire Committee when I say that we believe it would be a mistake for any member of this Association to design a new section which varies by the very smallest fraction of an inch from the sections we now have. We believe that the A. R. A. sections A and B are good sections. They have been designed from the point of view of people who look at this proposition from differing standpoints. Those who prefer the A. R. A. section A, ask for a rail of thin base, thin head and high moment of inertia. Those who prefer the B section are not so particular about the moment of inertia, but are quite particular about the thickness of the base and the thickness of the head.

We find when we compare some of these new sections that have been evolved that they do not vary and cannot vary very much from either one or the other of sections A or B, and we think that these very small variations will not produce any practical benefit. On the other hand, if the different members of the Association go ahead multiplying sections without regard to the work of this Association, this matter of the rail sections is going to get into the same chaotic condition that it was in before the A. S. C. E. sections were evolved. We all hope that there will not be too much work done in designing new sections until our Committee can make some more definite recommendation than it is ready to make at the present time.

Mr. J. L. Campbell (El Paso & Southwestern):—Has the Committee considered the practicability of having one weight of rail base to include several weights of rail, especially from 75 lbs. up? I think that matter is important. If we could get a rail of uniform base for varying weights, it would save expense by permitting old tie plates to be used with new rail and for other reasons the uniform width of rail base would be desirable.

Mr. W. B. Storey (Santa Fe):—The remarks of the chairman of the sub-committee, Mr. Trimble, seem to be directed against the Santa Fe system, as we changed the A. R. A. section 1-16-in. It was a very important matter to us, in spite of what seems to be considered a small matter in the discussion. It was due to the fact that we had an 85-lb. rail, for which we provided tie plates, over a very large mileage, and when we changed to the 90-lb. rail we changed the A. R. A. section so as to give the same base as the 85-lb. We were thus able to use the same tie plates as before we changed from the 85-lb. rail, and it saved us the expense of buying new ones. The expense connected with relaying the rail is very material to this case. I think Mr. Campbell's observations are very well made.

Mr. Trimble:—I had forgotten what Mr. Storey had done on the Santa Fe road when I made my remarks—they were not particularly

directed at that railroad. The suggestion has been made to the Committee of having rails of two or three different weights with the same width of base, in order that a uniform size of tie plate may be used without making changes. We have noticed, Mr. Storey, that not only your road, but a couple of others during the past year, have produced sections varying very little from the existing sections, but probably not for the same reason that you changed yours—that is a very good reason that you have given for the change you have made.

Mr. Atwood:—The next subject assigned to the Committee is, "Continue investigation of rail failures and deduce conclusions therefrom." The rail statistics for the past year have been placed in Mr. Trimble's hands, and he and his people have spent a great deal of time in compiling statistics and drawing conclusions. The compiling of these statistics and drawing conclusions has become a very arduous task, and the Committee has placed the matter in Mr. Wickhorst's hands, who has employed assistants to help him out in that work, so that in future this arduous work will be done by Mr. Wickhorst.

The matter under the heading, "Statistics of rail failures," is offered as information.

Mr. W. H. Courtenay (Louisville & Nashville):—I would like to secure some statistics from the various railroads regarding rail failures due to transverse fissures. Our road has been a great sufferer in that respect, and we would like to know whether other railroads have suffered from failures from transverse fissures. It seems to me that this is a live subject for the railroads for the reason that in nearly all other cases of failure that I know of there is some warning given before the rail breaks. When rails fail on account of pipes in the ingot, or cracks in the web, our people discover the flaws in the rails before they break altogether. But with a transverse fissure we have no warning, and we have had a good many broken rails from this cause. One-sixth of all the broken rails we had on account of transverse fissures caused derailments. It is very difficult to get records of failures from this cause, as a foreman or sectionman must be educated to know a transverse fissure where he sees one.

In the course of my experience on railroads I have seen many different kinds of broken rails, but I never saw a rail that failed on account of transverse fissure until February, 1911. Since then I have seen a great number. In order to educate our people to detect this flaw, and to be able to report it as such, I had photographs made and distributed them, and asked all the Roadmasters to bring that matter particularly to the attention of every foreman on the road, and whenever there was a case of transverse fissure discovered to report it to me. Such literature as I have seen on this subject so far does not explain it. We all know that the Engineer-Physicist of the Interstate Commerce Commission, Mr. Howard, attributes the failure of rail due to this cause to the simple reason that the rail is not strong enough. On the Louisville & Nashville road we have 70-lb. rails rolled under the same general specification, except that the carbon is lower than in the 80-lb. rail—rolled at the

same mill, same time, and same metal. We have never had a transverse fissure reported in the 70-lb. rail, although on some divisions we run the same weight of engine over the 70-lb. rail as we do over the 80-lb. rail. That appeals to me as powerful argument against the theory of Mr. Howard that the rail is not strong enough.

On many of the branch lines we have had 58½-lb. Bessemer rail in the track for many years and there have been no transverse fissures developed in that rail, whereas in the later 80-lb. rail, with the same weight of engines, we have a number of them. I admit that the rails are not strong enough since they contain flaws of that character, but if they did not contain that peculiar kind of flaw they would be strong enough.

I should be glad if the members here would give me some information whether they are having serious trouble of that kind. I believe that they have, but I do not know that it has been brought out. This transverse fissure is the most serious thing that confronts us in connection with rails. Rails with this defect snap quickly and there is no warning that they are about to break. Only recently have we succeeded in getting the trackmen to detect rails which have lateral cracks before they break across the section. There is sometimes a minute crack on the side of the head of the rail, which is discovered by the presence of a slight amount of rust running down the side of the rail. I have examined a great number of breaks from transverse fissures, and I believe every one of them is caused by an internal crack which extends to the surface of the rail. I have had a number of remaining parts of rails broken, the first fracture of which disclosed the fact that transverse fissures caused the rail to break, and found other spots or fissures, silvery gray, ranging in size from ⅛-in. in diameter to over half the area of the head.

Mr. Atwood:—The subject of transverse fissures is a live one with the members of the Committee. We recently had a meeting in Washington with Mr. J. E. Howard, the Engineer-Physicist of the Interstate Commerce Commission, and the purpose of that meeting was solely to discuss this question of transverse fissures. I think we left the meeting with a more satisfactory feeling all around as regards that particular trouble. There was some information developed during that meeting which we believe will lead to some solution of the cause of this class of failure, and which we hope will possibly result in eliminating these failures to a considerable extent. This is the subject before us which will be given serious consideration during the next year.

With reference to that particular thing, it comes under the next subject assigned to the Committee, (3) "Continue special investigations of rails." The matter which we offer under the third subject has appeared in the various Bulletins which you have had during the year and is offered as information. We will ask Mr. Wickhorst to speak on that phase of the report.

Mr. M. H. Wickhorst (Engineer of Tests):—As regards the developments of the last year, I may make a few remarks on the matter of broken rails and broken bases and their relation to seams in the base. Mr.

MacFarland has presented one or two reports dealing with seams in the base and shows up nicely how the seam is the origin of broken bases and broken rails. Two of the reports which have been given out during the last year have dealt with the origin of the seams in the manufacture of rails.

A seam in the base may be anywhere from a few hundredths to ¼-in. or more in depth longitudinal of the rail, anywhere in the base, and these seams also occur in other portions of the sections; but so far it does not appear that such other seams are a frequent cause of rail failures. But when they occur in the base, and particularly in the center of the base, running lengthwise under the web, or near that position, they are apt to be the origin of a broken rail.

These seams start in the ingot from which the rail was rolled. The ingot surface may be cracked transverse of the ingot, and in the rolling process, on the two sides of the ingot as it enters the rolls (the right and left sides) the cracks open up and produce gaps in the nature of zig-zag gaps. These gaps lengthen out more or less, later the sides of the gaps come together, and we have longitudinal seams. We start with a crack transverse of the ingot, or approximately so, and finally, due to the closing of the sides of the gap, the seam is longitudinal of the rail.

The matter of transverse fissures has been a very puzzling proposition, but it looks as if we had struck a trail that may lead us somewhere, although possibly the trail may prove to be simply a blind alley. We have given close attention to one rail and we find on examination that the interior of the head contained a great many fissures, not only transverse, but also longitudinal, oblique and in all directions; in other words, the whole steel was honeycombed with fissures. That is the result of a close examination of one sample, probably a typical sample. Just how this matter is going to develop we cannot say at this stage. While we might theorize and speculate, we cannot do more than that at this time.

As to the matter of rail statistics, the Committee six or eight years ago got up a form for compiling rail failure statistics, and then arranged to gather them, and we have now reached a point where we can in all probability make another step forward toward improving the value of the statistics.

The statistics as they will be issued some time in the course of the next few months, covering the year 1913, will be somewhat changed in this particular—heretofore the statistics have covered only the failures which occurred during the year included in the report. The statistics as we shall get them out hereafter, however, will include the accumulated failures, all failures which have occurred since the rail was put into service; for instance, for the 1910 rail, the report will show all the failures that have occurred since that rail was put into service up to the time covered by the report. We will start with the 1908 rail (for which, however, the reports are not very numerous), and all failures of the 1908 rail will be kept by themselves and separated according to the different mills. Then the 1909 rail will be treated in the same manner, the 1910 rail following.

and each year's rolling will be a complete unit. We hope in that way to be able to follow the improvement from year to year which may occur in the rolling of the various mills, or the lack of improvement, which we hope will not turn out to be the case.

Mr. Atwood:—I might, before starting on the conclusions, state that one of the meetings of the Committee was with a committee of manufacturers, and they brought up a number of changes which they would like to have made in the specifications, the large majority of which were not approved by the Committee, but there were some changes which the Committee thought it was advisable to make in the specifications. These changes are embodied in the specifications printed in Bulletin 164, page 375, and our conclusion is that the revision of the specifications for carbon steel rails presented herewith be approved for printing in the Manual. I would suggest if it is thought desirable that the seven different changes be taken up. The first change is in the first paragraph of section 1 as it appears on page 375. This is changed only by the words "and loaded," after the word "made," next to the last line. This change has been made to include section 35, requiring the loading of rails to be done under the supervision of the inspector.

The President:—If there is no objection, this section will be approved as amended.

Mr. Atwood:—Section 4 of the specification has been changed by substituting under the column "per cent. for open-hearth process," and "under 85 to 100-lb. rail, inclusive," the figures .62 to .75 for carbon, instead of what was in the old specification, .63 to .76.

The President:—If there is no objection to this change, it will stand approved.

Mr. Atwood:—The next change is the elimination entirely of section 6 of the old specifications. The principal thing which induced the Committee to eliminate that section was the fact that failures showing transverse fissures were as a general thing found where the carbon was high, and this section 6 allowed the carbon to be modified on a sliding scale, provided some other constitutents of the rail were in proper proportion. We, therefore, eliminated it so that it might not be possible to get carbon higher than as provided by paragraph 4 of the specifications.

The President:—If there is no objection, the recommendation will stand approved.

Mr. Atwood:—The next modification is in paragraph 13 of the old specifications.

(Mr. Atwood read the last paragraph on page 158 and the first paragraph on page 159.)

Mr. Atwood:—There has been some difference of opinion in the Committee with reference to this particular change. The majority of the Committee approved the change and the change was practically made to get to a common understanding with the manufacturers on every point where it was thought reasonably possible to do so.

The President:—Without objection the change will be approved.

(Mr. Atwood read the second paragraph on page 159.)

The President:—If there is no objection, this change will be made.

(Mr. Atwood read the third paragraph on page 159.)

The President:—If there is no objection, this change will be approved.

Mr. Atwood:—We therefore move that conclusion 1 be approved.

The President:—The Committee moves that the specifications for carbon steel rails, as published in Bulletin 164, be substituted for those which appear in the 1913 supplement to the Manual.

Mr. Atwood:—Mr. Wickhorst has already explained to you the reasons for these changes in the forms referred to in conclusion 2, in order that he might make more intelligible reports of the statistics of rail failures. We move that conclusion 2 be adopted.

(The motion carried.)

Mr. Atwood:—The Committee has one more conclusion to be acted upon with the consent of the convention. On page 157 there is shown standard drilling for four and six hole angle bars. This is a report of the sub-committee to the main Committee. At the time the report was printed the main Committee had not acted upon this, and it was not, therefore, presented in the conclusions. Since that time the Committee has approved the action of the sub-committee, and we, therefore, offer as the third conclusion that the drilling for the four and six hole angle bars, shown on page 157, be adopted and printed in the Manual as recommended practice.

(The motion carried.)

The President:—Any suggestions as to next year's work?

Mr. C. E. Lindsay (New York Central & Hudson River):—I have in my hand the statistics of the rail failures on 933 miles of main track on my division, which emphasizes to me in a peculiar way the effect of speed on rail failures. Tracks 1 and 2 are laid with 100-lb. rail, on stone ballast; tracks 3 and 4 are laid on gravel ballast, with mostly 80-lb. and 100-lb. rail taken from tracks 1 and 2 in previous years. Out of 232 failures of 100-lb. rail, 176 were on the passenger tracks and about 24 on the two freight tracks. Speed must have some very great effect on the breakage of rails, more than we have perhaps given it credit for.

The President:—I feel sure that the convention is proud of the Rail Committee and the work it has done. We feel that we can confidently look forward to the accomplishment of even greater work by this Committee. The Committee will be excused with the thanks of the convention.

Mr. Wm. R. Webster (Consulting Engineer—by letter):—The Association is to be congratulated on the effective work being done by its Rail Committee, their reports having steadily increased in value from year to year, and the recommendations they have made for work of investigation in 1913 are the most comprehensive and far-reaching of anything the Association has yet undertaken. It is to be hoped that funds will be furnished so that the tests and investigations may be carried through to completion during the next few years.

The general outline given by the Committee for work in 1913 and the points covered agree so closely with those in the "Suggested Lines for the Discussion and Investigation of the Physics of Steel," under which the papers of the Chicago meeting, August, 1893, of the American Institute of Mining Engineers (being part of the International Engineering Congress) were grouped and discussed, that I give below the table for comparison:

THE PHYSICS OF STEEL.

(See papers of Messrs. Martens, Osmond, Pourcel, Sauveur, Hadfield, Howe and Webster in Vols. XXII and XXIII).

The following lines of discussion are suggested, but are not in any way exclusive:

I. Correspondence between chemical composition and fracture, micro-structure and physical properties.

II. Influence of—
 (1) Casting temperature
 (2) Manner and temperature of heating
  (a) For rolling
  (b) For annealing
 (3) Work
 (4) Finishing temperature
 (5) Rate and mode of cooling
  (a) After forging
  (b) For casting
   on
  (a) Fracture
  (b) Micro-structure
  (c) Physical properties
  (d) Tensile properties
  (e) Residual stress

III. Segregation as affected by—
 (1) Composition
 (2) Casting temperature
 (3) Rate of cooling

IV. Blow Holes and Pipes: their volume and position as affected by—
 (1) Composition
 (2) Casting temperature
 (3) Casting pressure
 (4) Rate of cooling
 (5) Special additions
 (6) Forging

V. Hardening: relation between tensile properties and hardness of quenched steel, and—
 (1) Quenching temperature
 (2) Quenching medium
 (3) Size of piece quenched.

Much valuable information, especially on the heat treatment of steel, will be found in the original papers and discussions on the physics of steel, that extended over several years and are printed in the proceedings of the Institute.

The recognition by your Rail Committee of the valuable work done by the Ordnance Department of the Army at Watertown Arsenal a few

years ago is very gratifying to the members of the former Committee, under whose direction the tests were planned and carried out.

The transverse weakness in rail steel was first called to the attention of this Association by Mr. James E. Howard in his preliminary report on that Committee's work in March, 1908. Photographs are given in that report showing how the samples were taken in order to develop this transverse weakness. In cross-bending the flanges broke along the line of streaks in the steel and moon-shaped breaks of the flange in a full section of rail were made in the testing machine just beyond a similar break which had been caused in the track.

The head of a rail was planed down for the purpose of showing the streaks at different depths and sample bends of pieces 1-16 inch thick, cut from the head at different depths were exhibited to show the marked difference in the metal longitudinally and transversely. The longitudinal bends were very satisfactory, but the transverse bends cracked from end to end after they had been bent but a few degrees.

In discussing Mr. Howard's paper, the writer said:

"With this information before us, it is not hard to account for rails with a shallow head failing by the side of the head breaking off in service in the plane of web, but it is the strongest plea for making a rail with a deep head and a good large fillet connecting the head to the web."

These tests showing the transverse weakness of the rail did not make as much of an impression at the time as they have since, although Mr. Snow very soon afterward called attention to the great number of moon-shaped breaks in the flanges of the rails in service and the cause of same.

Mr. Wickhorst, in Bulletin 147, Appendix "D," refers to the soundness of acid open-hearth steel ingots made by the Standard Steel Works and the good results of tests on rail rolled from these ingots. These results confirm Mr. Howard's earlier tests made on bottom cast octagonal ingots, cast big end up, as made by the Standard Steel Works for tires in their regular every-day practice. The superior quality of the metal shown by Mr. Wickhorst's tranverse tests made on the flanges of an 85-lb. A.S.C.E. rail is remarkable. It would be very interesting to have some transverse tension tests made from the heads of this rail in order to show what the loss of tensile strength would be as compared with tests of similar pieces taken longitudinally from the heads. It is to be expected that the loss will be less than shown in his former tests made from Bessemer and basic open-hearth steel rail rolled under the ordinary conditions of manufacture.

If this is the case, the next step would naturally be to have a few heats of basic open-hearth steel made as nearly as possible under the same conditions used in making this acid open-hearth steel and make similar tests of ingots and rails rolled to the same weight and section in order to see just how much the process of manufacture has to do

with the results, that is, acid vs. basic open-hearth steel of the same longitudinal tensile strength.

Heavy draughts on the ingots in the first passes in the blooming mill, tear the metal and expose the honey-comb cavities at the outer edges of the ingot which become oxidized and do not weld up in the subsequent operations of rolling. This is clearly shown in forging blooms that are rolled from about the same sized ingots to about the same sized blooms as used for rails. Heavy reductions in rolling are desirable when the surface will stand them and when the interior of the mass is not too hot. Some mills that use very light draughts on their ingots from the first pass through, have little or no chipping on the blooms; other mills that take heavy draughts from the first pass through have often to chip as high as ninety per cent. of their blooms, and even with this chipping they have heavier rejections of the finished axles or other forgings. These defects in the rail blooms are often so lapped over and rolled in that they are not seen on the surface of the rail, but they exist and cause many failures. Any blow hole that does not thoroughly weld up is very much elongated by the rolling and helps to form planes of cleavage at right angles to the direction at which the pressure is applied. This trouble is generally attributed to poor material, poor rolling, or both, yet I believe it can be produced in rail rolled from perfectly sound steel that has received light passes in the blooming mill, or was not torn on the surface, as planes of cleavage may be developed, parallel to the web, in line of the flow of the metal, and at right angles to the pressure applied if too much work in rolling in one direction is put on the steel.

Re-heating rail blooms does not improve the quality of the rail as much as it should as the blooms have to be heated too hot in order to carry the heat through rolling and avoid finishing the flanges too cold.

The first experiments bearing directly on the formation of such planes of cleavage, in perfectly sound material, by pressure, were those of Dr. Tyndall in 1856, described in his lecture on Slates before the Royal Institution of Great Britian, from which the following abstracts are taken:

"Here is a mass of pure white wax; it contains no mica particles, no scales of iron, not anything analogous to them. Here is the selfsame substance submitted to pressure. I would invite the attention of the eminent geologists now before me to the structure of this wax. No slate ever exhibited so clean a cleavage; it splits into laminæ of surpassing tenuity, and proves at a single stroke that pressure is sufficient to produce cleavage, and that cleavage is independent of intermixed plates or scales. I have purposely mixed this wax with elongated particles, and am unable to say at the present moment that the cleavage is sensibly affected by their presence—if anything, I should say they rather impair its fineness and clearness than promote it.

"The finer the slate is the more perfect will be the resemblance of its cleavage to that of the wax. Compare the surface of the wax with the surface of this slate from Borrodale in Cumberland. You have precisely the same features in both; you see flakes clinging to the surfaces of each, which have been partially torn away in cleaving. Let

any observer compare these two effects, he will, I am persuaded, be led to the conclusion that they are the products of a common cause. (Note 1).

(Note 1—I have usually softened the wax by warming it, kneaded it with the fingers, and pressed it between thick plates of glass previously wetted. At the ordinary summer temperature the impressed wax is soft, and tears rather than cleaves; on this account, I cool my compressed specimens in a mixture of pounded ice and salt, and when thus cooled they split beautifully.)

"But you will ask me how, accordingly to my views, does pressure produce this remarkable result. This may be stated in a very few words:

"There is no such thing in Nature as a body of perfectly homogeneous structure. I break this clay which seems so uniform, and find that the fracture presents to the eyes innumerable surfaces along which it has given way, and it has yielded along these surfaces because in them the cohesion of the mass is less than elsewhere. I break this marble, and even this wax, and observe the same result; look at the mud at the bottom of a dried pond; look at some of the ungravelled walks in Kensington Gardens on drying after a rain—they are cracked and split, and other circumstances being equal, they crack and split where the cohesion is least. Take then a mass of partially consolidated mud. Such a mass is divided and sub-divided by interior surfaces along which the cohesion is comparatively small. Penetrate the mass in idea, and you will see it composed of numberless irregular polyhedra bounded by surfaces of weak cohesion. Imagine such a mass subjected to pressure—it yields and spreads out in the direction of least resistance (Note 2); the little polyhedra become converted into laminæ, separated from each other by surfaces of weak cohesion, and the infallible result will be a tendency to cleave at right angles to the line of pressure.

"Further a mass of dried mud is full of cavities and fissures. If you break dried pipe-clay you see them in great numbers, and there are multitudes of them so small that you cannot see them. A flattening of these cavities must take place in squeezed mud, and this must to some extent facilitate the cleavage of the mass in the direction indicated.

(Note 2—It is scarcely necessary to say that, if the mass were squeezed equally in all direction, no laminated structure could be produced; it must have room to yield in a lateral direction. Mr. Warren De la Rue informs me that he once wished to obtain whitelead in a fine granular state, and to accomplish this he first compressed it. The mould was conical, and permitted the lead to spread out a little laterally. The lamination was as perfect as that of slate, and it quite defeated him in his effort to obtain a granular powder.)

"The principle which I have enunciated is so simple as to be almost trivial; nevertheless, it embraces not only the cases mentioned, but, if time permitted, it might be shown you that the principle has a much wider range of application. When iron is taken from the puddling furnace, it is more or less spongy, an aggregate of small nodules; it is at a welding heat, and at this temperature is submitted to the process of rolling. Bright, smooth bars are the result. But, notwithstanding the high heat, the nodules do not perfectly blend together. The process of rolling draws them into fibers. Here is a mass acted upon by dilute sulphuric acid, which exhibits in a striking manner this fibrous structure. The experiment was made by my friend, Dr. Percy, without any reference to the question of cleavage.

"Break a piece of ordinary iron, and you have a granular fracture; beat the iron, you elongate these granules, and finally render the mass fibrous. Here are pieces of rails along which the wheels of locomotives have slidden; the granules have yielded and become plates. They exfoliate or come off in leaves; all these effects belong, I believe, to the great class of phenonema of which slaty cleavage forms the most prominent example. (Note 3).

(Note 3—For some further observations on this subject by Mr. Sorby and myself, see Philosophical Magazine for August, 1856.)

"I would now lay more stress on the lateral yielding, referred to in Note 2, accompanied as it is by tangential sliding, than I was prepared to do when this lecture was given. This sliding is, I think, the principal cause of the planes of weakness both in pressed wax and slate rock. Tyndall, 1871)."

I repeated this experiment years ago when a student, and can assure the Committee that it is well worth their while to do likewise, as one can hardly believe, without seeing it, that ordinary wax by simple pressure in one direction, can be made to split, like isinglass, in planes at right angles to the pressure. After having seen this, one can appreciate how sound steel may be made to split lengthwise and planes of cleavage be formed in the head of the rail parallel to the web at right angles to the direction of the application of the pressure in rolling, and on line of the flow of the metal.

It is very doubtful if we can ever get the same strength transversely in the head of the rail that we have longitudinally for there are other causes of transverse weakness where no cross-rolling or spreading is done to interlock the particles, for instance there is a loss in the transverse strength in universal mill plates as the rolling is practically all in one direction. The loss is not due to any overlap or longitudinal surface defects in rolling or edge work put on the ingot or bloom; there is not enough work to the vertical rolls to do much more than give good edges to the plates, still the weakness exists, the work is all in one direction and the particles are not interlocked as in sheared plates where the bloom is first spread by cross-rolling to get the required width and then rolled out lengthwise. In this way the particles of the steel are better interlocked and there is much less loss of strength transversely and the transverse bending tests are also better than similar tests from universal rolled plates.

Large steel angles show a tendency to split endwise, sometimes heavy angles on being sheared in 12-inch lengths will split from end to end at the root of the angle and the old opening and closing tests designed to check this defect, are often omitted.

Might it not be well to experiment with rectangular ingots so that a large part of the work to bring it down to a rail bloom, would be on the sides that would form the top of the head and bottom of the flange, thus any planes of cleavage that may be formed would be parallel to the bottom of the flange and the subsequent work on the other sides in rolling the rail, would not be so likely to form planes of cleavage parallel to the web, as under present conditions, and in this way help

to do away with split heads and moon-shaped breaks in the flanges.

Attention has already been called to the trouble caused by finishing the flange too cold in rolling while the heads, especially in the heavier sections, may be finished too hot. The internal strains left by these differences in temperature, and those due to the section of rail, naturally decrease its strength. Your Committee has already shown how easily a rail is broken when there is any small starting point for the fracture and how a longitudinal flange fracture may precede a square or angular break through the rail. It would be very interesting to repeat the recent tests on transverse ductility of the base of rails, given in Appendix "E," by supporting the flanges in the same manner and breaking them under the drop in order to see if there is any change in the character of the fracture from that produced by the steady pressure of the testing machine.

The investigation of Silvery Oval Spots, sometimes called "Transverse or Internal Fissures" in Rail Heads, by Mr. Cushing, Appendix I, is most interesting and instructive. Of course every effort will be made to try and find out if there are any other causes for such defects than those referred to by Mr. Cushing. With this in view, I desire to call attention to the following:

In 1901, Mr. C. H. Ridsdale read a paper on "The Correct Treatment of Steel" before the Iron and Steel Institute of England from which the following abstracts are taken:

"The cooling of steel, molten to critical point: When molten steel cools it crystallizes, the pure iron grains settling out, and the more quietly and slowly it cools, the larger they are. The last part to set contains more of the carbon and impurities, and may be termed the 'cement' which binds the grains together. If disturbed just as the grains are formed, this cement is still so liquid or soft that they have little or no cohesion, and the material is quite 'rotten' or red short in the extreme. At a little lower temperature it become cohesive and freely plastic, and it can therefore be readily worked, the cement being so soft that the grains, though cohering enough to permit this, are not held rigidly in their relative positions, but are able to move about each other so easily that they are not themselves appreciably broken up; and if the work is stopped whilst at this temperature, especially if the cooling is slow, the grain is found to be very large and coarse.

"In fact at this temperature the size and shape of the grain is not affected by work, only by the interferences and other conditions of cooling, and the piece exhibits no flow lines and has no rolling hardness. The larger the grain, however, the less coherent it is (owing to the larger area of the cleavage planes) if subjected to sudden shock; so the piece is wanting in toughness and may be actually 'rotten.'"

In discussing Mr. Ridsdale's paper Mr. J. E. Stead stated:

"The author had pointed out the bearing the dimensions of the crystalline grain had upon the strength. In the tension-testing machine they did not get much difference between a coarse-grain and a fine-grained crystalline steel when the strain was applied gradually; but under a falling weight the difference was most marked, and often the coarse-grained steel would snap like a carrot. Such fractures were not due to intergranular deposits, but to true separation of the cleavage

planes. The large crystal masses present large planes of weakness, and when a strain was brought to bear upon these crystals they separated through their mass, and once the cleavage was started it traveled rapidly from crystal to crystal through the whole section of the steel. When he was studying, many years ago, the crystalline structure of steel, he obtained very coarse crystalline steel, which elongated thirty per cent. in the testing machine, and yet when a small section was placed upon a V-block, and a sudden blow was given so as to put the under surface in sudden tension, on examination of the piece under the microscope, he found that one or two of the crystals in the center of the piece in which the cleavages happened to be vertical or at right angles to the surface, had fractured."

Is it not possible that the hammer blow of a flat wheel may start fractures in the head of the rail, as described by Mr. Stead, and thus cause a detailed fracture having this silvery oval appearance at the point where the fracture started, due to the surfaces moving slightly on each other before the final break took place; or might they not be started by heavy gagging in straightening?

This brings us back to the question of rolling green steel to which particular attention was called by the writer's chief assistant, Mr. F. L. Moister, in a discussion of the Association's rail specification in March, 1905. The injury that may be done to the internal structure of the steel by forging it under the hammer or press, is fully recognized and precautions are taken to avoid forging at too high temperatures. But the same precautions are not taken in the rolling mills and much good steel has been injured.

It would be very desirable to have some rail ingots rolled at as high temperature as they will stand in order to learn what the effect is on the internal structure at different stages through to the finished rail, which should also be finished as hot as possible in order to get the worst results. If the material in the interior of the ingot is in the condition referred to by Mr. Ridsdale there may be found both longitudinal and transverse defects, where the metal has been torn and not thoroughly welded up again during the subsequent work at lower temperature. A very small defect of this kind would be sufficient to start an internal transverse detailed fracture.

Internal fractures have been found in axles and other heavy forgings. In guns they find small defects that are known as streaks or ghost lines—if the line of this defect is circumferential to the bore it is not as injurious as when it is radial—many large guns have failed from this cause. One of the most likely reasons given for this form of defect is slight segregation, that is, a hard spot. We should look for this in all rails that fail from detailed fracture starting from the interior of the head.

Mr. Trimble's report on rail failures for year ending October 31, 1911, is very complete. One of its most surprising features is the great number of failures by split heads of the 135-lb. rail. A thorough investigation by the Committee of this rail is desirable in order to locate just what the trouble is so as to avoid it in future.

The increase in weight of rail has not been proportionate to the increase in wheel loads, rate of speeds and traffic. Of necessity the next step will be the general use of much heavier rail to meet present conditions, which are the most severe of any country in the world. But in designing these heavier sections the metal should not be used to make a much deeper girder to carry the load, or wider flanges to avoid the use of tie plates, or wider head to provide for side wear, unless the depth of the head is increased and larger fillets used to connect the web with the head and flanges so as to act as braces and prevent splitting of the head and flanges. Under these conditions there should be a very great increase in the thickness of the web and flanges so as to carry the load properly and avoid internal shrinkage strains. That is, a section of rail that approaches as nearly as possible the bull-headed rail but adhering to the flat base of the T rail. It would be an ugly looking section, but would do the work required of it. It should come from the rolls straight and require very little gagging. Until the section of rail is changed and work can be put upon the steel at such temperatures as to bring out its true value, it will be a very hard matter to say what is the best tensile strength to meet our severe service conditions and what chemical composition should be specified to produce the toughest and best wearing rails. The changes recently made in rail sections are a start in the right direction, but have not gone far enough.

At the present time the carbons in our rail are too high and in the foreign rail are too low for service here; there should be a happy mean that would meet our requirements better. Our T-rails rolled for export of low carbon steels to the foreign specifications, or of high carbon steels to American specifications, are giving as good service under the lighter loads and traffic conditions in foreign countries as rails from any other country, and show that our troubles are largely due to more severe service conditions.

With the proper section of rail and lower carbons the work of rolling could be done at much lower temperatures than at present and rail rolled under such conditions would be much tougher and give better wear than our present higher carbon rail. Why not roll a few thousand tons of rail of such improved section and lower carbon (about 130 lbs. per yard) and give it a thorough trial under the most severe service conditions.

Up to this time all tests made by your Committee to show the influence of finishing temperature on rail, have, of necessity, owing to its section, been made on rail rolled at higher temperatures than those recognized as necessary to get the best results from the same carbon steels in other lines of work. That is, the metal in no T-rail has, under present conditions, been rolled so as to develop its true value.

At the Twenty-fourth Annual Convention of the National Association of Railway Commissioners, their Committee on Rails and Equipment made a very exhaustive report confined almost exclusively to rail. It is

most conservative and full credit has been given to all who have been investigating this subject. Special reference is made of, and abstracts taken from, the work of your Rail Committee. The complete report can be obtained from the Chief Clerk of the Interstate Commerce Commission, Wm. H. Connolly, and is well worth the perusal of all the members.

The following is the closing paragraph of the report:

"Finally, your Committee would recommend the continuance of the Government tests of rails and ingots which were begun a few years ago and which are referred to in the body of this report. These tests were planned by a committee composed of Government officers and of high-grade experts from civil life representing both railroads and manufacturers. The tests were partially completed under the supervision of Mr. Howard, and the results embodied in a congressional report are recognized as of great value. The work was, however, stopped by the Government before definite conclusions could be reached. We believe that it should be continued along the same general lines as originally planned, and that special study should be given to rail steel made by the basic open-hearth process.

"JAMES E. SAGUE,
"WILLIAM J. WOOD,
"CHARLES E. ELMQUIST,
"Committee on Rails and Equipment."

The advisability of continuing this investigation as suggested under Government auspices is generally conceded. The natural starting point would be to have the original Committee called together to make a short report, giving their views on the results of the investigation already made, and any suggestions they might have to offer for the continuation of the work. The writer feels confident they would willingly do this whether they were connected or not with any future work.

The work already done on ingots, blooms, rails taken at different passes in the blooming, roughing and finishing mills, and finished rail, was on steel made under the ordinary conditions of manufacture. This was to show the original internal or external defects in the ingots as cast and how they were increased or decreased by the different operations in the rolling, specimens having been selected at each stage of the work.

The original plan contemplated making a similar series of tests for both Bessemer and open-hearth steels, manufactured under conditions purposely arranged to increase the defects found in the first series, in order to show whether our ideas as to the causes of the defects found in the first series were correct or not.

The next step was to be another series of tests on Bessemer and open-hearth steels, manufactured under conditions arranged to eliminate the defects, and based upon the information derived from the first and second series.

In Proceedings of the American Society for Testing Materials, Vol. VIII, 1908, page 48, is given the plan outlined by the Committee for the original work, treatment of ingots with diagrams showing location and treatment of cobbles for the tests; introductory statement by Major

C. B. Wheeler, Commanding Officer Watertown Arsenal, showing how the Committee was appointed and the members of same. Particular attention is called to those portions of Mr. Howard's report on this work on pages 71 to 73, as they show the initial points of rupture in the interior of the head and flange, developed in the testing machine, similar to those which produce the silvery spots.

The work of the original Committee was brought to a close by Act of Congress terminating all committees on which civilians and officers of the Army and Navy served, or for which Government funds were used. The Committee did not even have an opportunity to meet and make a report on what had been done up to that time, and there has never been any attempt at the interpretation of the results of the work done by that Committee, and for that reason the records are not as complete as they should be. It may take some time to have the Act of Congress amended so that funds could be appropriated for such an investigation, but in the meantime it seems desirable that the work should be resumed under the proper Government auspices and by a Committee similar to the original one, on which was represented the producers, the consumers and the Government, this Committee to outline a plan of carrying on the investigation which would be carried out in detail by the Government officials in a manner similar to the work already done at Watertown.

This work is so important and far-reaching that it should not be confined to any one Association, and the co-operation of those already interested in similar investigations would give it additional weight, materially assist in securing legislation that may be required for appropriating Government funds, and insure its being carried through to completion; but in the meantime funds will have to be raised from other sources to start the work and thereby save from six months' to a year's time.

In this connection, the following is quoted from a letter of one of the members of the former Committee:

"The views of Mr. Sague's Committee are interesting. First, as expressing the feeling that the results desired can be obtained without the necessity of Government inspection; and second, recommendation for the continuance of Government tests on rail and rail ingots which were begun a few years ago. To express it tersely, it would seem to me that what is needed at the present time is not Government inspection, but Government assistance. Having been a member of the original Committee, referred to by Mr. Sague, and knowing something of the work that was started and done, I feel that had this work been continued to a conclusion, some of the problems that are troubling the railroads today would have been solved. There is no question but that the work as originally mapped out was the most complete series of tests and experiments that had ever been suggested. A Committee consisting of representatives of the Government, consuming and producing interests, with sufficient funds to carry on the work as originally started, would, in my opinion, be one of the strongest moves that could be made at the present time."

DISCUSSION ON TIES.

(For Report, see pp. 725-858.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TIES.

GEO. W. ANDREWS.	L. A. DOWNS.
J. A. ATWOOD.	W. K. HATT.
E. H. BOWSER.	F. R. LAYNG.
W. J. BURTON.	C. E. LINDSAY.
W. M. CAMP.	G. J. RAY.
J. L. CAMPBELL.	W. B. STOREY.
C. H. CARTLIDGE.	R. TRIMBLE.

The President:—The report of the Committee on Ties will be presented by the Chairman of the Committee, Mr. L. A. Downs.

Mr. L. A. Downs (Illinois Central):—The Committee on Ties was assigned four subjects for this year's work, as shown on page 151. We do not make a report on the second subject, "Continue study of stresses to which cross-ties are subjected, and determine size required," due to the fact that this Association has appointed a Committee tc co-operate with the Committee of the American Society of Civil Engineers on Stresses in Track, and while we have been considering this question for three years and last year brought in a report stating that we would continue the subject, intending this year, through the assistance of Dr. Hatt and Prof. Albright, of Purdue University, the latter being a member of the Committee, to do some work, to make some actual field tests to determine the stresses to which cross-ties are subjected, yet the Committee felt very much relieved when they found that the engineering societies were going to undertake the investigation of this subject on a broad scale. The Committee recommended to the Board that this topic be not assigned to us again until the special committee which has been appointed by this Association (one member of the Tie Committee having been placed thereon) made its report.

The other three subjects we have reported on. I may say that these subjects were first assigned to this Committee three or four years ago, and we thought we would complete the work in one year, but the more we got into the subject the greater we found its scope to be, and while last year and the year before we made reports of progress on these different subjects, and expected to finish the work by this year, we find that we are not ready to make a complete report at this time. It may be several years before these subjects that are assigned to us will be finally completed and definite conclusions made.

As to the first subject, "report on the effect of design of tie plates and spikes on the durability of ties," inquiries were sent out to the various railroads in line with the letter shown on page 726—37 roads particularly

interested in this subject; 29 reports were received in reply, and of these 29, 27 agreed with the statements on page 729. We submit this matter to the Association for its consideration only as a progress report, because we feel that the Association should know what we are doing.

Appendices A, B and C, which fill up the latter part of our report, are based on tests made on the Santa Fe. A member of our Committee, whom I am very sorry to say had to leave last night, is one of the general officers of the Santa Fe, and through his work and the kindness of the management, we were able to show in our report this year some very good information, one subject being the comparative holding power of different pointed cut spikes and the other being the holding power of cut and screw spikes. The third subject covered in the appendices is "Effect of design of track spikes and tie plates on the durability of ties." The results of these comparative tests are shown in the appendices and are accompanied by numerous photographs.

I might say, in explanation, that in this report reference is made to the names of particular makers, which we regret, as it has been our custom not to mention the names of makers or trade names—the spike should be referred to as chisel-pointed, or diamond-pointed spikes.

The second subject on which we have reported is on the "Economy in labor and material effected through the use of treated ties, as compared with untreated ties." The matter relating to this part of our report will be found on page 728.

This involves the history and general questions that are brought out: on the bottom of page 743 is a formula that is worked out where one can arrive at the life or the saving made by the use of treated ties as compared with untreated ties, knowing the life and cost of the untreated tie and the estimated life of the treated tie.

The next subject and the last was the use of metal, composite and concrete ties. This is a report that we are making each year, and, of course, means no conclusion. It will go on indefinitely. The Committee is building up a history of metal, composite and concrete ties that will be valuable many years from now. We report on no patented ties or any kind of ties that are not found in some steam or electric railroad and actually in use, and the opinions of those ties are given us by the railroads which use the ties. Particular reference is made to the Jennings tie. Probably some of you remember that the inventor of this tie got his congressman from West Virginia to introduce a joint resolution in the House of Representatives in 1913. The resolution provided that the Interstate Commerce Commission be authorized to employ persons who were familiar with the subject and to investigate the spreading of tracks, etc., on railroads, to see if metal ties should not be used, and in addition to directing the Commission with regard to this legislation they would appropriate $25,000 for the investigation. We have a report on five of those ties that were put in on the Baltimore & Ohio Railroad. The ties were of no value. All the other reports on the metal ties, composite and concrete ties are found in the report, together with figures that

we obtained from railroads. I might add that the sub-committee in charge of this work makes frequent inspection of these different ties in order to keep in touch with the matter.

I will ask Mr. Burton, who is chairman of the sub-committee, inasmuch as Mr. Parker is not here, to lead the discussion on the subject of effect of design of tie-plates and spikes on the durability of ties.

Mr. W. J. Burton (Missouri Pacific):—The conclusions which the Committee prepared are on page 727. I will say here that the conclusion as to 7 in. is the result of the replies received from the various members of the Association, but as far as we know there is no way of actually determining the proper width from present data. We do not know whether it ought to be 7 in. or 7½ in., but the consensus of opinion was that 7 in. is the correct width.

The question of the holding power of the diamond-pointed cut spike is not new. We have had information in years previous on this subject, and we also give some information from tests on the Santa Fe, in one appendix of this report.

Mr. R. Trimble (Pennsylvania Lines):—There are two statements on page 727 which I think ought to be pretty carefully considered before accepting. The first is under (b). It is that second statement that I think there is some doubt about. There may be some places where that would be entirely true, but I happen to know a place where it does not appear to be true. The Pennsylvania System is conducting at the present time a series of experiments to determine the comparative value of screw spikes and cut spikes. One of these experiments is east of Pittsburgh and one is west of Pittsburgh, and on the experiment east of Pittsburgh, where the traffic is three times as dense as it is west of Pittsburgh, we have found that that statement is not exactly correct. The fact is the majority of our committee that is looking after this experiment is almost at the point of recommending the abandonment of the use of screw spikes for as dense a traffic as we have at that particular point, and the committee seems to be almost unanimous—I will not say unanimous, but almost unanimous—in the opinion that the cut spike is better than the screw spike. The experiment is still going on, but it throws some doubt upon that statement formulated by this Committee, and I think it should be accepted with caution, if accepted at all.

With reference to clause (b) on page 727, that is not going to prove true in this particular experiment. In fact, a great number of screw spikes have become loose, and they can be lifted up. They have experimented with several of the devices which have been tried abroad in order to repair and retain screw spikes. They have not yet found any satisfactory method of repairing the defects that have been caused by these screw spikes becoming loose, and I doubt very much whether it is safe to accept that as a definite proposition.

Mr. J. A. Atwood (Pittsburgh & Lake Erie):—I would like to ask Mr. Trimble if these experiments refer to the use of screw spikes, where the screw spike holds the rail? Screw spikes may be applied to the tie-plate and do not have to perform the office of holding the rail.

Mr. Trimble:—They hold the rail instead of the cut spike.

Mr. Atwood:—If the screw spikes were for the purpose of clamping the tie to the plate solely, those objections you raise would not apply.

Mr. Trimble:—They would, because we had those same experiments where the rail is fastened to the tie-plate independent of the tie, and we found the same trouble.

Mr. Downs:—I was interested in reading Mr. Cushing's report in Bulletin 165 on the use of screw spikes. I do not remember the date this experiment was made, but it was some years ago. I might say from the investigation that was made on the Santa Fe that they seem to have exactly the same trouble when they started. They did not know how to use screw spikes. If they had taken the results of their first trial with screw spikes, they would have discarded them altogether. If you will look at the photographs in Appendix C that were made purposely to substantiate the statements made on page 727, you will find out from those photographs how it is done, and they took a great number of them just to demonstrate. The report of Mr. Cushing's experiment with treated cross-ties and wood screws is in volume 15, Bulletin 165. It refers back to 1908. This report was made several years ago. Like a good many other things, the first trial sometimes does not prove satisfactory, and it is not satisfactory until the matter is studied and we undertand the proper methods for using such things.

Mr. E. H. Bowser (Illinois Central):—I would like to ask what is meant by the term "hard pine." I notice in a number of these experiments with spikes they use the term "hard pine."

Mr. Downs:—Mr. Parker, of the Santa Fe, is not here now, but I think it means heart pine. Maybe someone from the Santa Fe is here.

Mr. Geo. E. Rex (Santa Fe):—It is "heart pine" instead of hard pine.

Mr. Bowser:—You ought to say "heart long-leaf pine." In some of these cuts it does not look like long leaf pine, but looks like loblolly.

Mr. Trimble:—In the particular place where this experiment is being conducted, we have all noticed this: That with the amount of traffic going over that particular piece of road, in order to maintain a screw-spike track to perfection would require a great deal more labor than where we have the ordinary cut spike. We are not yet ready to give final results, but we are looking for the man who can tell us how to repair and keep up that track in service with the screw spikes in it.

Mr. Geo. W. Andrews (Baltimore & Ohio):—I want to go back to the question of heart pine. I think the explanation given by some of the gentlemen is wrong. Heart pine does not signify anything. Any pine has a portion of heart, loblolly or bull. In a great many sections of the country long-leaf pine is known as heart pine. I am of the opinion that the members of the Committee who used the term "heart pine" in the report had in mind long-leaf pine.

Mr. W. M. Camp (Railway Review):—The information that has been given me in regard to this question of flat-bottom tie-plates with screw spikes corroborates what Mr. Trimble has stated. Going back in the his-

tory of flat-bottom plates, one will find that the design of tie-plates started with a flat bottom, and the development has been that some projection on the under side of the plate has been necessary in order to assist the plate to stick to the tie. Any kind of projection on the under side of the plate, whether it be a rib or a claw, does assist the spikes very materially in holding the rails to gage. There is no question about that. I also think that there is no question about these under-projections having something to do with admitting water to the tie, and, therefore, affecting the life of the tie.

Screw spikes are being experimented with on a good many roads in this country to-day, and I think there are a good many men in this audience who can speak on the question as to whether they have found that a screw spike with a flat-bottom tie plate will hold the rail better than a drive spike with the same kind of plate. It is a live question to-day, this matter of screw spikes, and I think it would be a fortunate thing if this morning we could have a thorough discussion of this question. It would seem to be an important matter if we can do away with the ribs on the under side of a tie plate by the use of the screw spike.

I am gratified to find that the Committee has found it advisable to recommend the boring of a hole for the drive spike, because the reputation of the drive spike has suffered, in comparison with the screw spike, in that it injured the fiber of the wood. That comparison has never been fair, because the screw spike has been driven in bored hole, while the drive spike has had to make its own hole, and in this way injured the fibers of the wood, without question. If a hole was bored in the tie, a drive spike should not broom up the fiber any worse than the screw spike. By boring a hole in the tie the drive spike has a better chance, on its merits.

While the Committee states that 27 out of 29 replies support its conclusions, I would like to know whether or not the conclusion in paragraph (f) was based on the drive spikes there referred to as being driven in bored holes. If not, I do not think the conclusion is fair. If they compared the drive spikes set in the ordinary way with screw spikes in bored holes, I do not think it is fair to say, based on any experiments of that kind, that the screw spike in itself has made possible the longer life of the tie.

In conclusion (d) it seems to me there must be a typographical error of some kind—it does not make sense. As I understand it, there should be a period after the word "tie," in the second line of that paragraph, and it should then start in to read: "Tie plates less than 7 in. wide, for use with softwood ties, cut into the tie sufficiently in some cases to determine the life of the tie." Is that what the Committee means? That plates less than 7 in. wide cut into the tie so badly that it affects the life of the tie?

Mr. Downs:—That is what the Committee meant; it is not expressed as clearly as it should be in the paragraph (d).

Mr. Camp:—I think the phraseology of that paragraph should be revised to make it clear. I do not think it is clear in the way it stands.

Mr. Burton:—The Committee was not asked to report on the desirability of screw spikes or the desirabality of any particular shape of tie plate. The report is on the effect of the design of tie plates and spikes on the durability of ties. This is a little different from reporting as to the desirability of any one type or design, and I think this answers Mr. Camp's remarks in regard to the flat-bottom tie plate. The question of the desirability of the design does not enter into the matter except as it affects the durability of the tie; that is, affords protection to the tie from mechanical wear and decay.

Mr. C. E. Lindsay (New York Central & Hudson River):—It is my understanding that the report of the Committee does not carry with it any recommendations and that these conclusions which they have reached so far are the result of their study, and are offered to draw out further discussion for the benefit of the Committee.

I have read with very much interest Mr. MacFarland's Appendix B on the holding power of cut and screw spikes, and while I agree that the vertical pull on the spike is one means of determining the relative value of two appliances, I think probably the severest strain to which the ordinary track fastening of that kind is subjected is the horizontal component of the thrust, that is, in the plane of the tie.

I have conducted some experiments recently to test it in that way, by pushing the spike back through the tie—backing it through the tie as it would be backed by the ordinary pressure of the rail base against the spike. It brought out some very interesting figures. The idea that the vertical pull of the spike was the great strain on the spike has led some inventors to design a toothed spike, where one face of the spike was serrated or toothed. Tests of spikes of that kind show strains from 2,290 to 3,770 lbs., depending on the splitting of the wood in the sample. It required from 4,170 to 4,920 lbs. to push that same spike back through the tie. Another idea in the improvement of the ordinary cut spike was to change the section of it from a square to a truncated pyramid with the base against the base of the rail, with the idea of increasing the area so as to reduce the amount of "necking" of spikes. A spike designed along that line was tested and required from 2,610 to 3,850 lbs. to pull the ordinary spike, where the special spike took 2,290 to 3,090 lbs. In backing the ordinary spike through the tie, it took from 4,670 to 5,750 lbs., and in the case of the special spike it took from 4,470 to 5,740 lbs.

I believe that the work of the Committee in the testing of such appliances should be along the plane of the tie rather than to determine the pulling resistance of the spike.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—Mr. Lindsay's remarks remind me of the fact that we have made quite an extensive series of experiments as between cut spikes and screw spikes along the line that Mr. Lindsay mentions. Our data, while it is not in shape at this time, we hope will be put in shape at an early date, and we expect to give it to the Association in the near future.

I think it will show very conclusively that the screw spike does not only have a very much greater pulling resistance, but also a much greater lateral resistance to rail pressure, all spike holes being bored. In fact, as I remember it, in round figures the screw spike has at least twice the lateral resistance—I am sure it is more than that—of the cut spike. We have not tested these spikes on just a few ties, but we have taken several hundred ties of different kinds, selected ties of the different kinds of wood, seasoned them, treated them, and bored different size holes in the same specimen. We then compared the pulling and lateral resistance of both the cut and screw spikes. These tests were made by means of a machine which we secured in France especially for the purpose.

These experiments comprise several hundred, and probably run into a thousand. Some of them were tested before treatment, others immediately after treatment, and again others were tested after they had seasoned for a period of six months or a year. That is one reason why we are not yet through with the test. We do not want to make the data public until it is complete, but we have sufficient information to convince us beyond a question of doubt that the screw spike has a considerably greater lateral resistance than the cut spike.

As a matter of actual practice, we have been using on our lines screw spikes for two purposes—main-line work, both in renewals, and in construction work. We have been using a flat-bottom tie plate with screw spikes. We have had no material trouble with loose tie plates to date. What trouble we may have, of course, I cannot foretell. We have had no indications to date that the screw spikes are not going to be absolutely satisfactory in every respect.

On our eastbound main track, down the mountain, where we have a one and one-half per cent. grade, with the traffic running from ten to twelve million tons per annum, we have curves of 5 and 6 degrees, where we have had to change the rails regularly every year, since we have been using open-hearth rails. When we used the Bessemer rail we had to change about every four or five months. At the present time we get nearly a year's wear out of the best rail. We have changed the rail three or four times on some of the curves where we have screw spikes without having to alter the gage of our track, laying the rail in on the old tie plates. I think that is pretty good evidence that they are not giving a great deal. Of course, on the sharp curves we double spike inside, and in some places both inside and out. It is out of reason to expect that you will not have some giving with screw spikes with the flat-bottom plate where there is no lateral resistance other than the spikes themselves, where you have extremely sharp curves and heavy traffic, but we have found that is so little that it has not been necessary to regage our track.

We have in service a good many miles of solid screw-spike track. Over the entire line we have screw spikes which have been put in during the past four years in renewals, in some places on part of the ties, in some places not so many, in other places more.

The only material trouble we have had with screw spikes in maintenance work is where we have had one or two or three spike ties to the rail, and that has been in wet places, where there has been some little heaving in cold weather. In such places we have found that the cut spikes do not hold in the winter, with the result that we have had some screw-spike heads broken off under such conditions. In other words, we know the cut spike gives when the track heaves and tends to pull out. The screw spike will not rise with the heaving of a track, but may break off. Where we have all of our ties spiked with screw spikes we never have had a case of that kind occur, to my knowledge. We have had cases where screw spikes were broken off in being placed in service in white oak ties by not having the holes sufficiently deep. A man can break a screw spike in placing it in position, and that has been done. We have proven conclusively that that has been done, but where the holes are properly drilled and of sufficient size, not too large, there is no trouble in placing them and no trouble with them; at least, there has not been on our line in the last four years.

I do not believe we are going to have the trouble Mr. Trimble speaks of with enlarged holes, and I am sure our tie plates do not rattle. We had a few cases where they did, due to the fact that they were not properly set down when they were placed. If you do not set them down, it is because you are not looking after them. The screw spikes do not come up; they have not done so yet.

Mr. W. B. Storey (Santa Fe):—I ask the last speaker what kind of ties he uses.

Mr. Ray:—We have mostly long-leaf yellow-pine ties, although we have in service a good many chestnut ties, short-leaf pine, beech, some maple, and a great many red oaks.

Mr. Storey:—The reason I asked the question was that we have used the screw spikes on the Santa Fe System almost entirely in pine, most of it rather soft pine, and we find that the tie plate does not rattle after a week or two of service, by reason of the compression of the wood by the plate, and we have to go over the track a second time, sometimes a third time, in order to get the plate tight. I do not know as yet that the rattling will ultimately stop, because the plate continues to sink somewhat into the tie as time lapses. Of course, our plate will require tightening early in the application, due to the fact that we use a rib under our tie plate about ⅛ in. deep, and until that is pressed home there will be necessarily some loosening of the plate. Even after the rib has gone home, the plate still continues to sink into some of our ties, owing to the softness of the wood, and in that case it is absolutely necessary to tighten the screw spike.

We are making some experiments now with screw spikes, covering twenty miles of continuous track on low grade with the traffic all in one direction. We have other experiments in which the spikes are placed on single track, with only a few ties fastened with screw spikes. We also have places where screw spikes are applied without tie plates.

We do not feel in this case the experiment has been tried long enough to warrant our reaching definite conclusions. The tonnage on our lines is nowhere near that on the piece of track described by Mr. Trimble, and I can readily see how the expense of keeping the screw spikes in shape may be a determining factor in regard to that piece of track; not that the screw spike may not give better results than the cut spike, but the expensive maintenance under excessively heavy traffic, or under excessively hard conditions, may turn the question economically toward the cut spike.

I also think that there is very great merit in Mr. Camp's suggestion that the comparison should be made between the cut spike in a bored hole rather than a cut spike under the old conditions, which most of us know of. I think further that the compression of the fiber of the wood, in the manner described by Mr. Lindsay, will, after the passage of two or three years, considerably affect the comparison between the cut spike in the bored hole and one driven home in the ordinary manner.

The subject is one of very great interest. It is one that we should all observe closely, and we should give the Association the benefit of any knowledge that comes to us in regard to this subject, because it is something that will, in the end, make for great economy.

Mr. Trimble:—May I ask Mr. Ray if he will state the amount of tonnage passing over the line which he described?

Mr. Ray:—Ten to twelve million tons per annum, eastbound, on one track.

Mr. Trimble:—I am very glad Mr. Ray has given us those figures, because that helps us out some. On the tracks on which we are conducting our experiments west of Pittsburgh, we have just a little greater tonnage than that, and we have not had any trouble with the screw spikes on the test track west of Pittsburgh. East of Pittsburgh, however, there is just three times as much tonnage as Mr. Ray mentions on the particular piece of track to which he referred, and we are getting results three times as quickly as we are getting them in the other place.

Mr. Ray:—I would like to say one thing more about the question of the tie plate loosening. Our experience has been very much the same in reference to setting down the tie plates in softwood ties, that is, setting down screw spikes after the plate has been in some little time. I do not think that with the screw spike you can get away from the necessity of going over the track after they have been put in, and the plates have become set down in the ties. Our plates are absolutely flat on the bottom. We find in the case of our softwood ties, due to the compression of the fiber, even with perfect bearing surface there is some slight settlement. We have not had that trouble in the harder ties. I believe we will have trouble with the softwood ties regardless of the kind or size of plates, but as far as our experience goes, the spikes do not come up.

Mr. J. L. Campbell (El Paso & Southwestern):—It would be interesting if Mr. Ray would tell what trouble, if any, they have had in re-

moving and replacing these screw spikes in connection with the constant renewal of rail mentioned.

Mr. Ray:—We have had no trouble so far. I can see where there is liable to be some trouble. In the first place, one of the most aggravating things we have to deal with, and one which must be corrected sooner or later, is the matter of brine drippings from the cars. This Association has done what it could to remedy that condition, but the present condition must sooner or later be corrected. We handle a good deal of refrigerator freight. We have a lot of rusting of all classes of material in consequence. We find that the screw spikes are very badly rusted in places on curves where trains stop, or at certain points just outside of icing stations where there is a lot of brine dripping. I believe we are liable to have serious trouble with the heads of the spikes rusting to such an extent that it will be hard to get them out. That is a troublesome matter, but it can be overcome if the question of brine dripping is properly taken care of. In the same territory we always have trouble with the bolts between the splice bars rusting to such an extent that they soon stretch, and that is true with other track maerial which is exposed to the brine drippings. Where the brine dripping does not affect the track fastenings, we have no such difficulty with the screw spikes.

It takes a little longer, certainly, to lay rail where you must take out screw spikes, as compared with the cut spike. There is no question about that. It takes time, but there is no trouble.

Furthermore, we have not had any serious trouble with screw spikes on account of derailments. We had one case where some derailed cars took out all the screw spikes on one side of both rails for about two miles, and there was not one out of twenty of the screw spikes so badly injured as to affect this holding power, with the result that we operated the wrecking train over the track and took care of the wreck. That shows that the screw spike is able to hold the track and perform its function where the cut spike cannot.

Mr. Campbell:—I think it is brought out clearly by the remarks made by Mr. Storey and Mr. Ray that the statement in paragraph (b) page 727, "Flat-bottom plates used without spikes become loose and the looseness results in the mechanical wear of the tie; they are satisfactory when used with screw spikes," will be true and satisfactory only if you remember that you will have to follow up the inevitable settlement of the tie plate into the tie by turning down the screw spike. That will always occur, I am sure, with a softwood tie. To what extent it occurs on a hardwood tie I am not prepared to express an opinion.

In regard to the statement in paragraph (c), am I to understand that this paragraph states that a rib 3-16 in. deep will hold the tie plate to the tie? There is some question in my mind about that. I do not express a definite opinion, because I have not had experience with that particular kind of rib. But it has a decided V shape, and it does not appear that it would hold the tie plate to the tie. If there is any

member of the Committee who has definite information on this point, it would be interesting to have it.

Mr. Storey:—I can say definitely that it does not hold the tie sufficiently to prevent vertical movement. The sole intent of the rib, as used on the Santa Fe tie plate, is to prevent lateral motion, and was put on primarily to help us in holding the gage on very curved mountain work. We later found it was no detriment to the tie in that it does not cut the fiber, but compresses it sufficiently to take in the rib. Therefore, we consider that it does not let the water in or damage the tie in any way, and it has a tendency to hold the gage on tangent and other track.

Mr. Downs:—I would like to correct the impression that the work of this Committee is in any way to determine the relative merits of the screw and cut spikes. The only point about it is, so far as the Committee is concerned, as to whether it affects the durability of ties or not. The last remarks made by Mr. Campbell and Mr. Storey are probably directed to the work which the Committee has in hand, but the relative merits of the screw and cut spikes are not questions for this Committee to decide, except as they affect the durability of the tie.

Mr. Storey:—On the particular point raised by the chairman of the Committee, I would call attention to (d) page 727, where mention is made of the width of the tie plate as an element to determine the mechanical wear of the tie. I believe that is not the only element, but that the width and the length taken together are the elements that have to do with the cutting effect of the tie plate. This is because the purpose of the tie plate is to distribute the load over a greater area on the tie, and the width alone has nothing to do with the area. If we could make it 6 in. wide, a foot long and thick enough to prevent curling at the edges of the rails, we could distribute our load sufficiently to prevent a large amount of trouble. The statement as given in the report of the Committee should, I think, be changed to take in the full dimensions of the plate.

Mr. Trimble:—I do not think I was out of order to speak to paragraph (f). As I understand Mr. Downs, he is not speaking of the relative merits of screw spikes and cut spikes, yet paragraph (f) certainly brings out that comparison very plainly. My first remarks were addressed to that statement.

Mr. Camp:—The relative holding power of screw and cut spikes against the lateral thrust of the rail is very intimately concerned with the life of the tie. If the spike spreads it does not maintain the gage, and the holding power of the spike in that particular plan becomes so deficient that it must be pulled and set at another place in the tie. The boring of extra holes in the tie or the redriving of spikes always weakens the tie and therefore affects its life. It is a big point in favor of the screw spike if it can be shown that it offers better lateral resistance to the rail than the cut spike, and it is important to know that these experiments have been made, as Mr. Lindsay and Mr. Ray have stated.

There is no question about the screw spike having better holding power against direct pull than a cut spike. It is not worth while to conduct laboratory experiments to determine that matter—one can easily settle that question with a screw, a smooth nail and a carpenter's claw hammer. On the other hand, we must take into consideration that the standard cut spike of to-day is no larger than it was when tonnage was very much smaller than it is now, and when the weight of rail was perhaps 30 lbs. to the yard lighter. There arises a question whether an increase in the size of the cut spike would not work some improvement, especially when it is driven into a bored hole.

Mr. Ray's remarks are so pertinent in this connection that I wish he would cover still other points I have in mind. I would like to ask whether his screw spikes were driven by hand or by power appliances, and whether his experiments have been conducted long enough to determine the relative merits of screw and drive spikes in ties which have advanced well along toward decay.

Mr. Ray:—Screw spikes have been driven both by hand and by power. We have been trying to get a machine so that we could drive the screw spike down and have them driven exactly the same in each case, so the tests would all be alike. In the tests we thought it quite essential that the screw spikes be driven down with the same strain in each case. We had a good deal of trouble getting such a machine and we found it nearly impossible to get any sort of an electric appliance that would tick the current out at the right time. We had no end of trouble securing that result. Most all of our test work has been done by hand. In the field the spikes have been driven by hand entirely. So far as the holding power of the tie is concerned, we have in a great many cases taken out our old tie plates, or on track where we had cut spikes on curves we have put new tie plates in throughout. double spiked them with screw spikes and have found that we are getting a good deal more life from the ties which we otherwise would have had to take out. I speak especially of white oak. I think we have prolonged the life of the ties, and we have done the same on bridges where we had long-leaf yellow-pine ties; that is, put on screw tie plates throughout the entire bridge on old ties.

Mr. Lindsay:—May I ask Mr. Ray: With tie plates, the point of application of the horizontal stress is at the top of the plate and the point of resistance is at the bottom. Were your experiments conducted with or without the tie plates?

Mr. Ray:—They have been conducted in both ways, in most experiments without the tie plate. The difference would not be so material if the experiments were carried on with the screw spike and the cut spike in the same way.

Mr. Lindsay:—The first action of the movement of the rail is to bend the spike, and of course the rectangular section has greater resistance than the circular section. The first action bends the spike diag-

onally in the hole. It seems to me that would show considerable difference in the action of the two appliances.

Prof. W. K. Hatt (Purdue University):—Some question has been raised as to the relative transverse resistance of screw spikes and common spikes. An investigation of this and kindred matters has already been reported to the American Railway Engineering Association by the speaker, and the report will be found in Proceedings of 1910, pp. 827 to 857. This report covers the relative strength of various kinds of wood against the pressure of the rail, and the holding power of various kinds of screw spikes and common spikes. On page 856, Tables 5 and 5-A, it is shown that lateral resistance of both common and screw spikes was the same in the case of loblolly pine. These screw spikes were from ⅝ to ½ in. diameter of spike at root of threads. In case of the harder woods, the screw spike had a greater transverse resistance than the common spike. Since this report in 1910, the work at Purdue University has been extended to include the resistance of tie plates by force parallel to the axis of the tie. The tie plates included the various commercial forms, and were spiked to the tie both by common spikes and screw spikes. The transverse load was applied while a load of 30,000 lbs. rested on the rail in the direction of the weight of a locomotive.

The speaker would request the privilege of submitting an account of these later tests for the Bulletin of the Association.

It appears to the speaker that laboratory tests are a rather incomplete index to the thing we are trying to arrive at, viz., the best material and design for service conditions.

Mr. Burton:—I would like to ask Prof. Hatt if any experiments have been made in the laboratory with partly decayed ties, i. e., ties which have been in service two or three years. It has always seeemd to me that tests made on brand new white oak or first-class timber were hardly representative of the conditions in the track, and that a spike which might show favorable holding power in a new tie compared with some other spike would show the opposite result, or a less favorable result, in a tie partly decayed.

It is not uncommon to find cut spikes in ties which have been in service perhaps two or three years which can be quite easily withdrawn from the tie, sometimes even by hand, the tie being otherwise fairly sound and capable of performing its functions (other than holding spikes) for several years longer. In such ties the fibers surrounding the spike, which were bent down when the spike was originally driven, and to which are due a large part of the holding power of the spike, have become set or have lost their "spring," so that when the spike is withdrawn the hole is left full size. In the case of a screw spike, timber in the same condition would not allow the spike to be withdrawn.

Prof. Hatt:—The experiments we made were upon ties of loblolly pine, red oak, red gum, long-leaf pine, short-leaf pine, treated with creosote, zinc chloride and with crude oil.

After one end of the tie had been tested the other end was planted in the earth for the durability test. This set of ties has been now sub-

jected to the conditions of the surface ground for nearly four years. It is possible, therefore, to make tests of some of these ties that are partially decayed, and to determine the resistance asked for by the speaker. The tests will also determine the relative amount of rotting of the various timbers. The speaker hopes to prepare a report of this entire investigation for the Association at his earliest opportunity.

Mr. Ray:—Just one word more in reference to the experiments that we are carrying on. They were started for the main reason to find out what size of holes we should put in the different classes of wood for the screw spikes and also for the cut spikes, for the reason that we are boring and adzing all of our ties before they are treated. It is quite essential to have the proper hole in the tie. The experiments will plainly indicate that the different diameter holes will materially affect the holding power of the cut and the screw spikes, and our experiments were primarily for the purpose of determining the proper diameter of hole and not to tell us what we could expect in practice from the life of the tie.

The President:—This discussion indicates that much study is being given to this subject, and the Board of Direction would like to urge the membership to submit the results of any experiments for publication in the Bulletin. Mr. Ray, I understand, will see that this is done later, in respect to experiments he has conducted, and in view of the desire of the Association to make the Bulletin of maximum benefit to the membership, we trust that other members of the Association will submit articles similar to Appendix A. The next subject is on page 728.

Mr. Downs:—I will ask Mr. Lewis, chairman of the sub-committee on that subject, to lead the discussion.

Mr. E. R. Lewis (Duluth, South Shore & Atlantic):—It was thought by the Committee that the best information could be given to the members of the Association on this subject of economy of labor and material affected through the use of treated ties, as compared with untreated ties, by summarizing the literature on the subject and presenting it to the Association with some workable formula by which any intending user of treated or untreated ties might compare the two from a money basis and determine for himself, in the circumstances obtaining in his own particular case, which was the more economical. In the information presented there is such a formula, which was the subject of a thesis by Mr. Neil M. Campbell, and which seems to be most appropriate to this result. The report is presented as information.

The President:—The Committee submits no conclusions and offers this report as one containing good information. The intention is to continue the study. The next subject is on page 747.

Mr. Downs:—I will call on Mr. Layng to open the discussion.

Mr. F. R. Layng (Bessemer & Lake Erie):—In opening the discussion on this report I wish to emphasize the fact that we have had a great deal of difficulty in getting in touch with some of the members as to experiments they are conducting. If any of you know of experiments being made in your vicinity, or if you are making them on your own line, it would be of

material assistance to the Committee if you would advise us. If I am on this work next year, I promise you that we will not bother you any further than to ask you to let us know that you are making the tests, that you give us a plan and photograph of the tie you are using. Later we may get after you, but at the present we will not ask anything further than to get into the record the fact that you are making experiments. The report is historical. There are no conclusions submitted, and the only thing that I wish to call attention to particularly is the installation of a tie on the Pennsylvania Railroad, near Atglen, Pa. We consider it a very important installation and the Committee will watch it with a great deal of interest. On the Pennsylvania Lines at Emsworth there has also been an installation of a composite tie, which is worthy of study. This will be watched very closely. In this connection I want to say it is very hard to draw any conclusions from one, two or three ties put in the track. The Pennsylvania, in putting in a mile of track, have, to my mind—and I think my fellow-committeemen are of the same opinion—used a sufficient number from which conclusions can be drawn.

The President:—This Committee has continued this work about seven years and the report has appeared annually in the Proceedings. It is to be hoped the Committee may continue the same line of work for many years to come in order that a true comparison may be made of various designs of ties. Unless the members of the Association will furnish to the Committee the basic data for their reports, of course, there may be omissions from time to time, but it is hoped that the Committee may be able to get a full statement of the experiments which you may be conducting. The next question is, have you any suggestions to offer as to what work this Committee should do next year? The discussion this morning has indicated that the Committee is already considering some very live questions, and all of them will be continued in the program for next year.

Mr. C. H. Cartlidge (Chicago, Burlington & Quincy):—The Chicago, Burlington & Quincy, some years ago, made some experiments with concrete ties which did not prove very successful. It is probably useless to say that the cost of such ties at that time was quite prohibitive. The subject is still interesting. It is possible that a concrete tie may be designed which will stand up under traffic, and which will be sufficiently practical to compete with the wooden tie. There are a good many questions which arise regarding design. One of the more important ones, to my mind, is how much can we afford to pay for a concrete tie in order to make it a commercially practical tie. I believe, after investigation, that a practical tie can be designed, one that will last as long as a wooden tie, or sufficiently longer to warrant our going into it, but it is necessary to know how much we can afford to pay for it. I think the Committee can handle this better than any one person. I will suggest that an investigation be made as to the amount which can be paid for a tie which will give a life of, say, thirty years.

Mr. Layng:—I think Mr. Lewis' report (sub-committee No. 3) this year answers that question directly. One can make the necessary assumptions and arrive at the consequent result. Mr. Lewis' formula gives a method of figuring, but you will have to make your own assumptions.

Mr. Downs:—I would like to add that the Committee appreciates very much the discussion here to-day by Mr. Trimble, Mr. Ray, Mr. Storey, and others, on our report, because our report is not yet completed. We expect to do considerable work on it. What has been said here to-day will be a great help to us in our future work.

The President:—The discussions indicate that the convention appreciates the work of this Committee. The Committee will be dismissed with the thanks of the Association.

DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 859-904.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

A. S. Baldwin.
E. H. Bowser.
Moses Burpee.
W. M. Camp.
J. L. Campbell.
C. H. Cartlidge.
W. A. Clark.
W. H. Courtenay.
Curtis Dougherty.
J. B. Jenkins.
Maro Johnson.
J. R. Leighty.
E. R. Lewis.
C. E. Lindsay.
B. H. Mann.
Hunter McDonald.
G. A. Mountain.
L. S. Rose.
H. R. Safford.
C. H. Stein.
Francis Lee Stuart.
John G. Sullivan.
S. N. Williams.

The President:—The report of the Committee on Signs, Fences and Crossings will be presented by the Chairman, Mr. C. H. Stein.

Mr. C. H. Stein (Central Railroad of New Jersey):—Mr. Chairman and gentlemen, as this is the period of the convention when the Chair is accustomed to saying, "Be brief, please," I shall endeavor to pass over as rapidly as I can the substance of this report. The Board of Direction assigned three subjects to this Committee, given on page 859.

With regard to the subject of continuing the investigation of ways and means for securing a proper quality of fence wire, I would say that this subject seems to have been worn almost threadbare, at least the Committee in its investigations has not seemed to be able to make any progress, and therefore is passing over the subject at this time very lightly and suggests to the Board of Direction that we discontinue it for a few years at least, until manufacturers are able to tell us a little more about it, along the lines of certain suggestions that have been made from time to time; also to give the railroads that are investigating the matter on their own initiative an opportunity to determine the results to be obtained from several different forms of wires that have been under investigation. One of them is the sherardized, another the special galvanized, the latter seeming to meet with most favor.

In regard to the subject of concrete and metal for signs and signals, as compared with wood, the Committee prepared a series of questions and promulgated them among the railroads with a view to securing information in regard to the subject, and received replies from a vast number of railroads with regard to a multitude of signs, both affecting the employes and the public. The Committee realized that it was rather a ponderous task to undertake, and, therefore, concluded at this time to devote itself

more particularly to the two signs that seemed to be of primary importance—the public road crossing signs and the trespass sign.

You will note on page 862 that the Committee has tabulated the substance of the replies received, indicating under proper headings the name of the railroad and the style of signs, giving dimensions, etc., together with the inscriptions and other information. However, this Committee worked up a typical form of sign which it thinks will best meet the present conditions. By way of interjection I might mention that on page 868 it has presented also six typical signs that are in use by the different railroads; all of the various signs in use come under one or the other of those types. It also secured from the legal departments of the various railroads information in regard to the statutory laws in effect in the various states, also the Public Utility or State Railroad Commission rulings covering the different forms of road crossing signs prescribed. I might say that it would be very apropos here, after our study of this subject, to repeat the words of Cowper, that "The earth is made so various that the mind of desultory man, studious of change and pleased with novelty, might be indulged." It appeared to us that that sentiment is carried out in the different forms of railroad signs that the railroads in this country and Canada have adopted. We were finally able to determine upon the design of a sign that we thought would best meet the most general conditions and requirements. The Committee, therefore, in its consideration of the subject concluded that the objects to be achieved in the selection of a proper sign were—

"Reasonable cheapness in first cost, economy in maintenance, which includes durability, and the merit of serving the purpose for which it is placed; that is, to give proper and ample warning of the existence of a railroad crossing."

On page 874 we present a sign made of cast-iron and wrought-iron pipe. The Committee does not feel at this time like recommending this wrought-iron pipe sign because of its high cost. Furthermore, it is not certain whether it has the feature of durability about it. That has to be determined a little later on, by further experimenting. This sign has only been in use about a year; so that the Committee is not willing to make any recommendation as to the practicability of this sign.

We have presented in Appendix A a list of the different States covering their requirements for road crossing signs, as well as the rulings of the Public Utility Commissions. These laws are not complete for the reason that it was impossible to secure all of them from the legal departments of the railroads, but we have that under way, and I think by this time we have secured all the laws in effect in this country.

The Committee at this time would like to recommend the adoption of the specifications and the plan for highway crossing signs as shown on page 873. I move the adoption of this recommendation.

The President:—The Committee moves the adoption of recommendation 1 on page 872, which carries with it the illustration on page 873, together with the specifications on page 872.

Mr. Curtis Dougherty (Queen & Crescent):—I would like to ask if the Committee considered the use of reinforced concrete posts for this sign, and if so what were the considerations that led to the rejection of that form of post?

Mr. Stein:—In behalf of the Committee I would say that it does not believe in speculation, and we were only able to get a report from one railroad that was using a concrete sign, and from one other that was using concrete posts. The information secured, therefore, on this subject was so meager that the Committee could not feel justified in going on record and recommending anything in regard to concrete signs. It would have done so if there had been any information available of sufficient importance.

Mr. J. L. Campbell (El Paso & Southwestern):—I would like to ask the chairman if the Committee has found that the word "locomotive" is more generally used than the word "cars" on crossing signs.

Mr. Stein:—Perhaps Mr. Campbell has not read the entire text of the report. The Committee does not propose to confine the wording on the sign to "Railroad Crossing," "Look Out for Locomotive," because we refer in the text to the fact that local conditions will have to be complied with, and wherever the law requires "Look Out for the Cars," those words must be substituted for "Locomotive," but the words "Look Out for Locomotive," seem to be so well adapted to this sign, and since a number of railroads are using it, we thought it was best to use it for typical purposes.

Mr. C. E. Lindsay (New York Central & Hudson River):—I think the Committee has very properly selected this sign as the most important sign on a railroad. It is supposed "to stand by the side of the road and be a guide to man." I feel, however, that whatever this Association does will be taken as a guide by public bodies which have not already established standards. The Public Service Commission, second district, New York State, is about to adopt a regulation of this sort, but is probably awaiting the action of this body regarding a sign before doing so. I was born and reared with this kind of a sign, so I am not opposed to it, per se, but the more I see of conditions around highway crossings, and the increasing number of paved streets with curb lines, requiring signs to be set on the curb lines; and the increase in size, velocity and character of vehicle traffic on the highways, the more I am impressed with the fact that such signs so placed are hardly visible. A post standing on the curb line is on a line with trees, poles and other obstructions. This sign has a blade, with less than 4 ft. projecting out over the roadway. When I first went into New England I rather sneered at the type of railroad crossing signs in use there. It is the shingle type, 10 or 12 ft. long, sticking out over the road, and the more I think of it the more I admire it as a proper device. The sign must be made more visible than this sign is. It is not sufficient to put up a sign of this kind; we ought to adopt a sign that will give better results in this respect. A great many of the laws which are quoted here, which do not specify a particular type of sign, say

that the sign must be *across* the highway, intimating that there must be some structure across, above the road. I believe that is the only kind of a sign anybody will pay attention to. I think it is inadvisable for this Association to adopt the words "Look Out for the Locomotive." The fundamental words are, "Stop, Look and Listen." That is the law in most of the States. Those are the words which I think should be given special prominence.

Mr. Stein:—I will answer Mr. Lindsay by questioning his last statement. I will ask him whether he can find in any one of the laws that are quoted in this book, which are supposed to be transcripts of the statutory laws, a requirement on the part of any State or a requirement on the part of any Public Utility or State Railroad Commission, that the words "Stop, Look and Listen" should be used in any of the States.

Mr. Lindsay:—There is more than the laws you have read. You must read the interpretation of the laws by the courts, and every court has said it is the duty of everybody to stop, look and listen. I believe that answers you.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—The chairman of the Committee has stated that he was unable to get information as to reinforced concrete posts. I believe it was probably due to the fact that the Committee's circular of inquiry covered only reinforced concrete posts for these particular signs. The use of concrete posts is quite universal for a great many purposes, and there is no reason why they could not be used in this connection. The line with which I am connected has used reinforced concrete posts for supporting bridge warning signs for the past seven or eight years, and we have found them very satisfactory. I therefore move to amend the plan of the Committee on page 873, by a note adding the words, "Unless made of reinforced concrete."

A Member:—I understand the purpose of that is to make it optional.

Mr. McDonald:—That is the purpose of it. We are confined in this sketch to a wooden post.

The President:—The Committee states that they have no objection to the amendment, and by unanimous consent this note will be added.

Mr. C. H. Cartlidge (Chicago, Burlington & Quincy):—It might be inferred from the wording proposed by Mr. McDonald that a reinforced concrete post as outlined in the drawing would be sufficient. I would suggest that the Committee be requested to present a design for reinforced concrete posts.

Mr. Stein:—We did not have sufficient information to warrant us in stating that a concrete post might be used in place of a wooden post. Only two cases have come to our notice where railroads were using concrete posts for crossing signs. While the Committee is willing to accept this amendment, it is not prepared to say, as has been suggested by Mr. Cartlidge, that a reinforced concrete post made up similar in design to the wooden post would meet the conditions. From the practice in the country to-day I do not believe that the Committee is warranted in specifying anything other than the wooden post. Notwithstanding the fact that

the Committee has accepted this amendment, I believe that we ought to go a little slow in adopting it. Just because one or two railroads have tried out the concrete posts and have felt that their experience with it has justified their continuing it is not sufficient. I would much prefer to see the sign go through in its present design. Mr. Lindsay said that whatever the Association did on this occasion is what railroad commissions are going to adopt, and it was really our purpose in undertaking this work during the past year to accomplish this object. We felt that something would have to be adopted that all railroads, with slight variations, could accept, and, therefore, we ought to become sufficiently progressive to get there first with our recommendations and not to depart too far from the standards in use on the different railroads of the country. This sign seemed to us to typify the very thought and sentiment of a railroad crossing, and it appealed to the judgment of the Committee. I feel sanguine now that the commissions of certain States which have thus far not adopted any road crossing sign would gladly accept this one, and several States that have already adopted road crossing signs have adopted signs similar in type to this. I think we are getting in harmony not only with the thoughts of the Public Utility Commissions and the State Railroad Commissions, but also with the feeling of the railroads in regard to this matter. I think it would be better for the Association if this sign were adopted now and if found expedient an addition could be made to the Manual a little later on and a concrete post could be recommended by this Association. If in the meantime certain railroads feel that this sign is all right except that they would like to adopt the concrete post, there is no objection to their doing so.

The President:—In looking over the specifications, I think it is the intention of the Committee simply to present this as a wooden sign, with a wooden post. The introduction of this clause, "unless made of reinforced concrete," will require the Committee to recast its specification.

Mr. McDonald (reading conclusion 1):—There does not appear any specification for the sign on page 873, but a note is given. I, therefore, can see no conflict in the words which I propose to add to the sketch, which is covered by the conclusions. There may be some conflict in the text which is not covered by the conclusions. As to the chairman's remark about not being able to get the information, it seems to me that the very wide use of reinforced concrete telegraph poles should have been sufficient notice to the Committee that such a thing was possible. I know of a large number of instances where reinforced concrete posts as high as 30 ft. are loaded down with considerably more weight than these signs would impose. As to our ability to design them with sufficient strength, if they are made 8 in. square, I think there is no doubt about it.

The President:—Mr. McDonald is correct in his observation. However, the Committee intend that the specification on page 872 should accompany the diagram on page 873, yet that is not stated in the conclusion.

Mr. Stein:—That was due to the manner of setting it up in the book. That was intended to accompany the diagram.

Mr. McDonald:—If the specification is to go with it the addition of the words I have mentioned would cause a conflict. I think then the Committee might take up the question of a revised sign next year, omitting the kind of posts. The Committee says, "creosoted at the bottom." My idea of creosoting is that it is impregnated with creosote. This is only a coat, and I think you are wasting money putting it on.

Prof. S. N. Williams (Cornell College):—I think it is a deplorable fact that there are people who will disregard all warnings, no matter how plainly they are expressed. I remember an instance during the past year in Iowa, where a gentleman traveling with his family insisted on trying to make a certain crossing in front of a fast train, and as a result three members out of four of that family were killed and the automobile was smashed. I remember an instance recently in Chicago where a man insisted on going under the bars of a railway crossing where they were set to try to keep people from crossing, and as the result he was killed. There have been instances also of people trying to cross the Chicago River when the signs were clearly against them. I remember an instance in my town not long since where a runaway team ran three-quarters of a mile to make the railway and then turned and ran three-quarters of a mile along the railway in order to meet a fast train and be killed and have the vehicle smashed. I feel from the standpoint of my own limited observation that the railways are doing all that can be expected by any reasonable person to secure the safety of the public in crossing their tracks and that a very large proportion of the accidents which are happening at crossings are due to the positive wilfulness and neglect of people in insisting on doing things they know they ought not to do, when every possible effort has been made to prevent their doing them.

Mr. E. R. Lewis (Duluth, South Shore & Atlantic):—In Appendix A, I do not see anything about the height of sign in the regulations of Canada, but I recollect having heard that in Canada they stipulate that the minimum height for crossing signs shall be 16 or 20 ft. The higher you get a sign the more costly is the maintenance, because the wind has a greater effect on a high sign than on a low one.

Mr. Lindsay:—I feel that road crossing signs, as designed in most cases, are not sufficiently conspicuous to serve practical purposes, and they are becoming less so, in thickly populated districts, because they are forced to the side of the road, to the curb line. If we are to adopt a practice which merely meets the letter of the law, this will serve the purpose as well as anything else, but if we are to adopt a sign that will meet the spirit of the law and give reasonable warning to the public, I think this sign will fail. I move that this sign be referred back to the Committee for further study.

Mr. G. A. Mountain (Canada Railway Commission):—I agree largely with the Committee's design of the sign. Mr. Lindsay speaks of the sign being placed at the curb or outside of it and that it cannot be seen.

That may occur in a few cases. We have had some inspections of accidents where that did occur. That is, it could not be seen on one side of the crossing. I notice by this pamphlet that Rhode Island requires a crossing sign on each side of the crossing. I do not think that is necessary, but there are cases where you might place a sign on one side that will serve pedestrians or vehicles coming from the other side. I think that might be taken into consideration.

Mr. W. H. Courtenay (Louisville & Nashville) :—The Committee has produced a sign which is in common use, the lettering of the sign differing in various sections. It is the practice on road crossings, where there is heavy traffic or at crossings where trains cannot be seen a long distance, to erect a special audible highway alarm, visible where the view can be had and audible where it cannot be seen. I think the recommendation of the Committee does not prevent roads adopting highway signs, audible or otherwise, in special cases.

Mr. A. S. Baldwin (Illinois Central) :—I concur with the views of Mr. Courtenay. Where special conditions exist they can be met by special signs, but we do not wish to go to too great expense in adopting expensive devices for very general use, and in many places where the travel is slight. I wish to call attention to a remark made by Mr. McDonald as to creosoting the post for a length of 6 ft. I think that should be corrected on the drawing. It is not practical to creosote 6 ft. of a post. On the Illinois Central we creosote the entire post and get good results from it. The comparison between the capitalized cost of the creosote and the concrete post from the Committee will be interesting.

Mr. Campbell :—The Committee has brought in a plan of crossing sign which I think is as nearly a standard in common use as any other. I think the Committee's work is good. I do not believe it should be referred back to them for the reasons stated by the two gentlemen who have preceded me. If there are special conditions requiring special signs they should be handled accordingly.

Mr. Moses Burpee (Bangor & Aroostook) :—I do not want to find fault with the recommendations of the Committee, but would like to suggest something simpler. The more you put on a sign, the more you defeat its purpose. I think there is too much lettering, and the letters are so crowded as to make them almost illegible at a distance. It seems to me the words "Railroad Crossing" are sufficient for the purpose of warning, and if those words only are used, it will be sufficient. I think the use of two boards is good, because the form of the letter X indicates "crossing," and it is more conspicuous. I have seen the same form used, with the word "Railroad" on one board and the word "Crossing" on the other.

Mr. Stein :—Before the question is put to vote, I would like to sum up again what the Committee had in view. Its chief object was, knowing that the different States were going to require the railroads to put up certain kinds of signs, to prepare a sign that would meet the approbation of the States that have already adopted certain signs, and at the same time meet the general views of the railroads that have signs already

in use. Referring to page 871, you will note what inscriptions the different States require. The inscriptions will have to meet local conditions. The Committee tried to meet the general conditions. If we fail to adopt a sign at this time it inevitably will come about that the different States will prescribe different forms of signs and there will be no uniformity at the railroad crossings, which is so much desired. If all railroads in the country would adopt a uniform crossing sign, I think I would be almost safe in saying that it would be unnecessary to put any words on the sign, because everybody would understand it to be a crossing sign.

Mr. Lindsay:—The National Association of Railway Commissioners has under discussion at the present time the propriety of the adoption of a uniform sign throughout *all* the States. While that body has no power to require that, the States generally follow its lead. My object in asking the Committee to reconsider this subject is to seek a design of sign that can be built and maintained practically at no greater expense than the sign proposed, but which will better meet the conditions. A sign across the road is illuminated at night by the headlights of an automobile. This sign is never seen until after the accident has happened. These signs are required no matter what other devices you put up. I ask for a more conspicuous road crossing sign.

Mr. Cartlidge:—I believe the members will agree with me that the Committee has done its work well, and I believe that work should be recognized by the convention. I think from the discussion that there are two things required. Both are of sufficient importance to require consideration. One is the matter of creosote. There has been no dispute of the assumption that we had better creosote the whole post, if we creosote any of it. It has been clearly brought out that in many cases the words "Look Out for the Locomotive," or "Look Out for the Cars," are not required. It is evident also that the letters are very close together on the sign. It seems to me that an amendment could be made to the report providing for the use of the words "Railroad Crossing" on the two arms, occupying the whole of it, and that any other additional words that may be required could be placed on the post, as is done by many railroads to-day.

Mr. J. R. Leighty (Missouri Pacific):—It seems to me that the recommendation that the Committee has worked out is in line with the general practice in the country to-day, and that if this report be referred back to them, because the sign they propose is not always visible, that it should be referred back with specific instructions that they shall work out a sign that cannot be placed in any position where it cannot be seen from all directions.

Mr. Francis Lee Stuart (Baltimore & Ohio):—I hope that the Association will adopt a standard crossing sign. We should compromise our differences about non-essentials and recommend or adopt some sign which can be published, and be distributed so as to help influence legislation in the right direction. If an Association like this cannot agree, how can we expect States and Public Service Boards to agree?

Mr. John G. Sullivan (Canadian Pacific):—It appears that we are nearing an agreement. I agree with one of the speakers that if the words were put on, "Railroad" or "Railway Crossing," and any other words added, that we would get the necessary results. Why not adopt the simplest sign, with the least requirements, and put on such words as may be required? We are going to make a mistake if we think that we can lead legislative bodies. I would move an amendment to this, that we use the words "Railway Crossing" or "Railroad Crossing," using two boards for the sign. The cross is a good indication of what is meant.

Mr. J. B. Jenkins (Baltimore & Ohio):—I think the objections which Mr. Lindsay states can be answered. In nearly all of the places he spoke of in which this crossing sign is not suitable, crossing gates are needed. We are consuming a great deal of time, but I think it is important to have this crossing sign adopted to-day. That can be done by making two or three motions to test the sense of the meeting. I would second Mr. Sullivan's motion, to get the matter started.

Mr. Stein:—In regard to what Mr. Sullivan and Mr. Jenkins have stated, and answering Mr. Lindsay's objection, the Committee did not care to treat of that feature of the case where signs could not be properly seen because of intervening trees or other obstructions, but you will note in the text a statement in reference to the sign not being clearly seen 150 ft. from the crossing, that then another sign shall be erected 150 ft. from the crossing. The Committee did not want to say anything about that at this time. They thought perhaps the question would come up. They felt constrained to omit any reference to that in this report, because they felt it would bring up discussion that would be unnecessary now. If you will read the specifications you will see that the Committee has made no reference to the wording that is to be on the sign, in view of the fact that local conditions require different wording, and this was simply typical of the wording and style of the lettering. If it is the sense of the Association that they want any specific wording on the sign, all that it is necessary to do is that someone make a motion that the wording shall be "Railroad Crossing" or "Railway Crossing." It is not necessary to substitute anything for the present wording, because no wording exists at present on this sign.

The President:—The question is on the adoption of that conclusion. Mr. Stein moves that the design on page 873, together with the specification on page 872, be adopted. Mr. Lindsay moves an amendment to the effect that this subject be referred back to the Committee for further study.

(The amendment was lost.)

The President:—The amendment has been lost. The motion now is that the design on page 873, together with the specifications on page 872, be adopted, as recommended practice.

Mr. E. H. Bowser (Illinois Central):—I ask the Committee if it will accept the suggestion Mr. McDonald makes, that it is useless to paint it with creosote and no railroads have plants with which to creosote part

of the post. Has the Committee any objection to fully creosoting the post? That is in accordance with present practice.

Mr. Stein:—Can you paint the post after it is creosoted?

Mr. Bowser:—You can, but it will not stick very long.

Mr. Stein:—That was the objection to it.

Mr. Courtenay:—That is a good objection. You cannot paint a creosoted post.

Mr. Bowser:—Why is it necessary to paint the post?

Mr. Courtenay:—We paint on our posts, "Stop, Look and Listen." It has been of service to our railroad in damage suits.

Mr. H. R. Safford (Grand Trunk):—I think we are going too far in specifying creosoting in any form, whether by painting or treating. The use of the creosoted timber posts is purely an economical question. There is a large portion of the country in which a railroad would not be justified in using creosote, where the cost of the untreated timber is so low and the cost of the treated timber so high, that it would not be logical to use it. It seems to me the Committee goes far enough when it specifies the size of the post, the height, etc., and the determination as to whether it should be treated or untreated should be left entirely to the local organization.

Mr. Campbell:—We tried the experiment of using a creosoted post for our property line posts, but discontinued it because the post could not be painted successfully. The creosote came through the paint and destroyed the lettering. We finally adopted the practice of dipping that part of the post to be in the ground in hot coal tar for whatever such practice is worth.

Mr. Safford:—I offer my suggestion as an amendment, that all reference to the subject of creosoting be omitted from these specifications.

Mr. W. M. Camp (Railway Review):—I do not want to speak on the amendment. As I understand it, the Committee has not recommended any specific wording of the sign.

Mr. Stein:—No specific wording, only size of letter.

Mr. Camp:—In order to facilitate matters, would it be agreeable to the Committee to leave off the lettering on this sign?

Mr. Stein:—The lettering is put on there simply to show the size of the letter, etc.

Mr. Camp:—This lettering has proved a stumbling block in the consideration of this report.

Mr. Stein:—We might insert something to the effect that other language could be used.

Mr. Camp:—I think that would be a good thing.

Mr. Stein:—The Committee will accept that.

Mr. Sullivan:—I think, as I said before, that it might be well to show the general plan of the crossing sign, but to leave the wording optional.

The President:—The Chair was about to call attention to that question and ask whether or not the Manual will contain this illustration ex-

actly as it is shown here. It is my understanding that the Committee does not intend the lettering shall appear on the design as recommended. Will the wording appear in the Manual?

Mr. Stein:—It may be omitted.

(Mr. Safford's motion carried.)

Mr. Campbell:—Is there not a motion before the house that the words "Railroad Crossing" be used in lieu of the wording suggested by the Committee?

The President:—The motion to recommit having been voted down, the motion introduced some time ago by Mr. Sullivan and seconded by Mr. Jenkins is now in order.

Mr. Sullivan:—I move that the wording now shown on the sign be changed to either "Railway Crossing" or "Railroad Crossing," and that it be stated that the type of letters and size of letters shown are simply typical.

Mr. McDonald:—I am anxious to see this go through and I think it is an important matter that we should lead legislation, if it is possible. I am anxious to see it go through in the shape in which it is. The illustration should show the lettering as a sample with "Railroad Crossing" or "Railway Crossing" and there should be a note stating that the inscription on the sign is to conform to the local legislation. If that is done, then we are not committed to any lettering.

I want to call attention once more to the fact that in adopting this conclusion we are adopting the sketch only, and nothing whatever in the text.

Mr. Stein:—The Committee states with the permission of the convention it will accept the changes indicated in Mr. Sullivan's motion.

Mr. McDonald:—Will the Committee accept the further suggestion that a notation be added that the inscription on the sign shall conform to local conditions?

Mr. Stein:—That is the feeling of the Committee.

The President:—Without objection on the part of the convention, the Committee will accept that modification.

Mr. Jenkins:—As I understand it, the amendment which was made to this section, with reference to concrete posts, has created some confusion, and I offer a further amendment that the clause inserted in regard to concrete posts, which has been accepted by the Committee, be stricken out again, and that the title of the sign be changed to read, "Wooden crossing sign."

Mr. Courtenay:—I desire to appeal to this convention to adopt the Committee's recommendation just as it stands. It will then give each railroad company the privilege of putting on each sign such lettering as best suits the local conditions of each individual road, and it appears to me that that will be far more satisfactory.

As to this question of creosoting the bottom of the post, there is no prohibition against it, if anyone wants to do it, and naturally these mat-

ters of detail can be decided by the individual road. The Committee's conclusion, it seems to me, is best for the convention to adopt.

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I suggest, in order to clear up this matter, that the words "Railroad Crossing" on the one panel be left there, and the other panel be left blank; the style of lettering and specification to indicate something else can be put there.

The President:—Mr. Jenkins, do you desire a vote on your motion?

Mr. Jenkins:—Unless the Committee sees fit to accept it. The design on page 873 was amended by an acceptance of a suggestion by the Committee to print words something like this: "Excepting where concrete posts are used;" the striking out of the part in regard to the creosote leaves that meaningless, and I think it is necessary to indicate that this is intended only for a wooden sign, provided that the Committee thinks a separate design should be inserted for the concrete. I make this suggestion in order to get the matter straightened out. If the dimensions are good for a concrete post also, then it is not necessary to put in the word "wooden" in the title, but simply to strike out the clause in regard to concrete posts.

The President:—The motion is that the original motion be amended so that all reference to concrete be omitted and the title be amended to read "wooden crossing signs."

(The motion was carried.)

The President:—Mr. McDonald makes the suggestion that the conclusion on page 882 does not include the design shown on page 873.

Mr. Stein:—I want to say that was simply due to a typographical error. When the copy was prepared the plan appeared in connection with the specifications and under the same number. The Committee could not get in their copy the number of this page in the book and we had to rely on the printer to insert that. It so happened that the specifications appeared on a different page from the plan, as you will note, and that is what made the conclusion seem at variance with what the book contains. The intention was that the specification, which is only one paragraph of about twelve lines, describing the sign, should be included as part of the plan and in explanation of it.

Mr. Courtenay:—Should there not be a reference to the page?

Mr. Stein:—Yes, a reference to pages 872 and 873.

The President:—The explanation given by the Committee is to be considered as indicative of the intent of the Committee, which is that the design on page 873, together with the specification on page 872, as now amended, is to be adopted as recommended practice for publication in the Manual.

Mr. Stein:—The next question taken up by the Committee was the consideration of trespass signs.

In like manner we secured the statutory laws throughout the United States and Canada and prepared a synopsis, as you will note by the Bulletin, and also secured from the railroads of the country the different forms of signs in common use and it was observed that there were no

statutory regulations with regard to the form of the signs, the character of the wording to be employed, etc., except in the State of Pennsylvania. That State stipulates that the sign shall read: "Notice—This is private property and all persons are hereby warned from trespassing thereon under penalty of the law, as provided in the Act of Assembly passed April 14, 1905." That is the form of wording which the Pennsylvania law requires on the "No trespass" signs displayed in that State. I have not personally seen any of these signs, although there may be many of them which have that wording.

The Committee presents a form of design which would seem to meet most generally with the requirements under this heading, and they have prepared a plan of trespass sign as shown on page 881. I want to make it clear again that the wording on that sign is not the wording the Committee recommends. The Committee simply presents it as the typical form of wording. The sign as placed in the Manual may be blank, if so desired. The Committee recommends the plan and specification for public trespass signs as shown on page 881. The specifications do not appear on the same page of the Bulletin, because of the explanation made.

I want to say, in conclusion, both in regard to this road crossing sign and the tresspass sign, it is not a matter of snap judgment with the Committee. I think I am safe in saying that the Committee spent several months in giving very close study to all the plans presented before they arrived at conclusions for presentation to the Association, and there is a long line of work yet mapped out for them in connection with the signs which will come before them in the year to come; the Committee, therefore, moves that the specification and typical design presented on pages 880 and 881 be approved and printed in the Manual.

Mr. Lindsay:—There has been some comment regarding the wording of the sign. I understand the Committee is willing to put any desired wording on the sign, or to leave the wording off—

Mr. Stein:—Yes.

Mr. Lindsay:—While the laws may specify signs in one State to be in a certain form, I know the interpretation has been made in some of the States that unless the sign contains the name of the railroad company it does not fulfill its legal purpose. Anyone could put up a sign, "No trespassing," but that would not be a proper defense for the railroad company unless the sign bore the name of the railroad company.

Mr. W. A. Clark (Duluth & Iron Range):—In some parts of the country hunters with high-powered rifles find railroad signs a very convenient target, and it seems to me that a sign of steel or of wood would not be damaged to the extent that a cast-iron sign would be if used in this manner. I think the cast-iron sign would be pretty badly shattered if it were struck by a bullet.

Mr. Campbell:—We are using steel for such signs and think it is well to do so, but I do not care to make an issue of that. Would the Committee have any objection to omitting the diameter of the pipe? Boiler

tubes vary in diameter and this detail could be left to the judgment of the railroad company. Any old boiler tubing on hand could be used.

Mr. Stein:—Nearly all of these details are optional with the railroad company, but we must stipulate something that would seem to be most harmonious with the general design of the sign. If a railroad company does not desire to follow our recommendation, and wishes to use a pipe ½-in. smaller or larger, it is optional with them, but we must give them something harmonious with the general plan.

The President:—The question is on the adoption of the conclusion as recommended practice.

(The conclusion was adopted.)

Mr. Stein:—There is one more item, and that is the subject of the investigation of concrete and metal as compared with wood for fence posts. The Committee has prepared to make an exhaustive series of tests in regard to this, and if Mr. Johnson, a member of the Committee, is present I think he could probably say a few words in regard to what the Committee is doing, and that will conclude our report.

Mr. Maro Johnson (Illinois Central):—The matter is pretty well covered in the text of the report. We have had concrete posts made by a number of different railroads and propose to have these broken later under a variety of conditions, carrying out as far as possible conditions met in the actual use of the posts.

The President:—Are there any suggestions regarding next year's work of this Committee?

Mr. B. H. Mann (Missouri Pacific):—The Committee reports that the subject of fence wire should rest for a year, but judging from what is said in the Bulletin it might be just the other way. The galvanizing specifications are those in use by several associations. One manufacturer said he could not meet the galvanizing tests of this Association which have to do with the making of joints. If the joint corrodes faster than the fence itself, it reduces the life of the fence. As the structure as a whole should be judged by its weakest parts, I suggest that the Committee be asked next year to take this feature up with the manufacturers.

Mr. McDonald:—I do not know whether what I am about to suggest is within the province of this Committee or not, but I think some committee of this Association should study the question of the equitable and practicable apportioning of grade separation expenses between the community, the steam railroads and the electric railways.

The President:—The suggestion of Mr. McDonald will be taken up by the Committee on Outline of Work and turned over to whichever committee seems to be the proper one.

In excusing this Committee, we want to call your attention to the very large attendance, and in so far as the Committee is concerned, I think the discussion of the convention is a sufficient compliment for its work.

DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

(For Report, see pp. 905-912.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

WILLIAM MCNAB. S. N. WILLIAMS.

The President:—The report on Conservation of Natural Resources will be presented by Mr. McNab, the Chairman of the Committee.

Mr. William McNab (Grand Trunk):—The purpose of this Committee has been set forth in the first paragraph of the report. It may be assumed that every member has read the subject matter and matters contained in these few pages, and, as it is merely a report of progress, one of information, rather, I will move that this report on Conservation of Natural Resources be received as information and progress.

Prof. S. N. Williams (Cornell College):—Gentlemen of the Association: While this subject is not as technical and, perhaps, as peculiarly interesting to railway men as some other subjects which have been ably discussed by the committees, yet it is really one of the most important subjects before railway men and people of the entire country at the present time. The late honored A. M. Wellington, in the introduction to his book on the "Economics of Railway Location," said that the first idea in connection with railway construction was the avoidance of waste. In conversations with students I have tried to impress upon them the necessity for economy of time, money, energy, space and material. These matters are just as important to the general public as they are to railway companies.

I have been pleased recently to see a statement made by the Chicago, Milwaukee & St. Paul Railway Company that it was trying to increase the car loading of freight trains. Last year 1,683,000 cars were underloaded, and if the loads on each car had been increased two tons, $2,500,000 would have been saved the company. Only a small part of the earning capacity has been available heretofore, and it is just as important to other railway companies as to that company to thus economize. Incidentally, the company is trying to avoid unnecessary delay in the use of freight cars. As I came into Chicago the other day, I noticed a long line of freight cars down a siding, extending perhaps half a mile, and wondered what all of these idle cars meant. I suppose they are being held in reserve for the handling and movement of the crops.

I have been interested also in seeing a statement made which came from another railroad company as to the number of persons who have been killed and injured in accidents on their tracks and in various other ways. This is no reflection on the company, because it is undoubtedly as

careful as other companies are in handling their trains, but it was a comment on the danger of trespassing—the loss of life and injury to people attendant upon their being in places where they ought not to be, and that subject is increasingly important.

Sanitarians are trying to impress upon us the great waste of human life and loss to humanity by unnecessary sickness. One of our members told me a short time since about the great trouble and expense to which he had been subjected in trying to save the life of his wife who had been ill with typhoid fever, one of the preventable diseases. It is also one of the most common diseases, and yet it is one which can be largely attributed to human negligence.

I was interested in looking over a report presented at our meeting yesterday to see the effort of Mr. Beahan, one of the Engineers in charge of operations on the Belt Line Railway around Cleveland, to arrange the work so that there should be no delay to trains, and the work of construction should not interfere with the work of the management of the car line.

These are only a few instances which occur of things being done by railroad companies over the country, and we are coming to have efficiency engineers who show us how we should avoid unnecessary effort in doing work. The subject of handling freight was mentioned in one of the discussions at the meeting yesterday, so this matter of economy is coming to be one of the most important things in connection with the working of railways as well as everything else.

We have had presented to us recently by one of the great Chicago dailies the matter of wasted lumber caused by forest fires. We are all familiar with that, and this Committee has previously called attention to it. I think, however, it might be well to note that a recent report of the National Conservation Commission estimated there were 65,000,000 acres of land denuded in our country when the report was made five years ago, and if we assume only one dollar per acre as the loss by denudation there would be $65,000,000 to be made up in some way, which means a general movement toward reforestation. I think three states at least are providing for this. The subject of improvement of waste land is important to railway companies, because it involves the subject of ties. We have had an able discussion of this presented by the Committee. I notice no reference was made, as in years past, to the efforts of railroad companies to provide for the growth of new ties, but this subject of reforestation is of great importance to railroad companies because of the question as to where are we to get a supply of railway ties after the present supply is exhausted.

I would like to appeal to the organization as men and brothers to make conservation a habit, if I may term it such, or a specialty. You are accustomed to do that already in the avoidance of unnecessary railway expenses. All business organizations are making efforts to avoid unnec-

essary expense and waste. We have had our attention directed previously to economy in the various materials used by railways, and the effort to make their money go as far as possible.

I appeal to you to do all possible with your ability and opportunity in trying to impress upon the people of our country the necessity for economy. I think men who have the management of railways have produced most valuable results. They have shown great sagacity and skill in enabling railroad companies to pay dividends when circumstances were so much against them as they have been. They have done extremely well, and yet all of us have an opportunity to produce that which is so necessary, namely, a proper appreciation by the people of the value of economy and the avoidance of waste in every direction; in doing that we will not only benefit the railroad companies, but also do that which is very important—impress upon the public the necessity of learning to exercise the same economy, thrift and careful management which is shown by the people of Europe and possibly many other countries.

The President:—The report will be received as information, and the Committee relieved with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

(For Report, see pp. 913, 914.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

C. P. HOWARD. HUNTER McDONALD.

The President:—The next report will be that of the Committee on the Economics of Railway Location. In the absence of the Chairman, Mr. C. P. Howard, the Vice-Chairman, will present the report.

Mr. C. P. Howard (Consulting Engineer):—This Committee has no conclusions or data to submit at this time. There are two reports, a majority and a minority report, given in Bulletin 164.

The President:—This question of furnishing funds to the Committee is before the Board of Direction and is under consideration. The Board will decide at a convenient time as to whether any appropriation can be made or not. The convention understands there has not been sufficient funds in the past for any experimental work, and in so far as the Board is concerned, the matter is still under consideration with no final action taken.

The Committee makes no recommendation, but simply outlines the general ideas with respect to the future work of the Committee. It is only necessary, therefore, to accept this as a report of progress. The Committee is relieved with the thanks of the Association.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 919-921.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

L. C. FRITCH.	W. B. STOREY.
HUNTER McDONALD.	C. A. WILSON.

The President:—In the absence of the Chairman, we will ask the Vice-Chairman, Mr. C. A. Wilson, to present the report of the Special Committee on Uniform General Contract Forms.

Mr. C. A. Wilson (Consulting Engineer):—It seems as if the Committee should have been able to complete the work which was assigned to it. At the first meeting of the Committee a form of proposal and a form of bond were practically agreed to, but later on in the year there came up some questions as to the bond which were brought up by such important interests that the chairman of the Committee thought it advisable to have another conference of the full membership of the Committee, and, therefore, we have asked for further time on that matter.

The other matter submitted is a minor change in simply one word which the Committee feels that in the next printing of the Manual should be added. The Committee on page 919 recommends the insertion of the words, "losses," "and," in the contract form.

(The form of proposal and the change recommended by the Committee were approved.)

Mr. L. C. Fritch (Canadian Northern):—This Committee has now discharged its duty, apparently, which the Board imposed upon it, which was to draw up a uniform general contract form. The Committee reported a form last year which has been adopted very largely.

The question of the construction bond is purely a matter which the legal departments can handle, and it would be my recommendation that the Committee be now discharged with the thanks of the Association.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—My belief is that if this matter is left entirely to the legal departments of railroads, it will not be properly attended to, and I am in favor of continuing the Committee and let them consult with the legal departments if necessary.

Mr. W. B. Storey (Santa Fe):—The Committee in its report states "that the Committee be instructed to complete the bond form, and submit it to the legal departments of railroads for criticism." I do not believe we will get any satisfactory construction bond by the end of next year, if this matter is referred to each railroad. I feel that each road has to take care of its own bond and the legal department will furnish such

bond as may be necessary. I do not think there is anything further in the work of this Committee which pertains to this Association.

Mr. Wilson:—The Committee last year, if you will remember, thought it was through when it performed the service of preparing the contract form, and asked to be released. The convention saw fit to give the Committee this further work to do which they have not yet performed. I do not agree with the gentleman that the bond is any more of a legal proposition than the contract.

Referring to the form of contract, we submitted that to the legal department of all the railways and got answers from all those who were willing to answer. It was a composite proposition, it was the result after the reception of the opinion of the various legal departments of the railroads which considered it. We feel that if the construction bond is presented to the legal department of the railroads, we will get a composite proposition and have a construction bond which will represent the best opinion of the legal department of the roads.

The President:—The Committee is excused with the thanks of the Association.

DISCUSSION ON RECORDS AND ACCOUNTS.

(For Report, see pp. 923-960.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RECORDS AND ACCOUNTS.

A. W. Carpenter.	C. P. Howard.
W. A. Christian.	J. B. Jenkins.
L. C. Fritch.	Henry Lehn.

The President:—The report of the Committee on Records and Accounts will be presented by Mr. W. A. Christian, the Chairman.

Mr. W. A. Christian (Chicago Great Western):—Bulletin 164 shows the subjects assigned to this Committee, and I do not think it will be necessary for the Chairman to read them. The first one, with regard to making a comprehensive study of the forms in the Manual, has been up so often it seems to me everybody is familiar with it; but I may mention it is difficult to get information from the various roads as to forms, the usual reply being, "We do not use all the forms in the Manual."

Your Committee submits conclusions regarding the revision of the Manual, beginning at the bottom of page 923.

(Conclusions 1 and 2 were adopted.)

Mr. Christian:—In regard to the information on page 924, following conclusion 3, I think it would be well if a conference between our Association and the Accounting Officers' Association could be arranged regarding the subject of these forms.

The President:—For the information of the convention, the Chair will state that the Board of Direction will take up this question in accordance with the ideas of the Committee and endeavor to get some action on it.

Mr. Christian:—Your Committee has received from the Interstate Commerce Commission the symbols that they have used on maps and profiles and we have embodied these symbols in the proposed changes to our Manual. Your Committee submits these signs or symbols to the convention and recommends their adoption.

Mr. A. W. Carpenter (New York Central & Hudson River):—This matter of symbols is certainly a very important one, for the reasons which the Committee has pointed out. I find a number of the symbols which I believe can very well be modified. On page 931 the third symbol from the top is for the "Street, Block or Other Property Line." The third symbol below that is for the "Company Property Line." We have to show on the right-of-way maps to conform to the Interstate Commerce Commission specifications, the separate land parcel lines. It is very confusing if these are shown as full lines, because there are so many other full lines, and I would recommend that some form of broken line be

adopted. On page 932 there are symbols for crossings—these might apply very well, perhaps, to very small-scale maps, but in the case of crossing bridges, they do not seem to be adequate or in keeping with the other symbols for bridges which somewhat indicate the type of construction. The crossing gate sign is a difficult one to make and could be simplified by simply using four lines in a diamond shape, without filling in and putting the additional work on in the middle as shown.

On page 934 the mile-post sign shown is rather difficult to make. It would seem a circle would answer quite as well, and be very much easier to make in good shape.

At the bottom of page 935 the last symbol is for a signal bridge. This is shown as a heavy straight line with a projection at either end. Comparing it with the symbol for culverts on the top of the next page, it will be seen that on a map the signal symbol would appear very insignificant in comparison. It would be more correct, I think, to use double lines for the signal bridge, connecting them with diagonal lines to represent bracing, and with cross lines at the end. On page 936, under Miscellaneous, the symbol proposed for the Pole Wire Lines becomes very difficult to show on small-scale maps, because it occupies so much space transversely. If the circles representing the poles were placed on the longitudinal line, it would seem to answer the purpose quite as well and be better generally.

In looking these symbols over rather hastily, I do not find any for electrified track construction, third rail, transmission lines, etc.

Another point is in connection with the colors, where red ink is mentioned. That becomes of some importance in connection with tracings which it is desired to reproduce. Ordinary red ink lines will not reproduce satisfactorily by the processes that are now in general use. Orange lines, however, will produce well. I would suggest these matters be taken into account by the Committee.

It is very important, in my opinion, that the Association authorize the revision of the conventional signs for maps and profiles at this meeting on account of the valuation work which is going to require an unusual amount of map making, which should be on a uniform basis and, furthermore, the specifications for maps and profiles of the Interstate Commerce Commission in connection with the report of this Committee, read as follows: "The symbols used on all maps and profiles shall be the standards recommended by the American Railway Engineering Association, in so far as they may be applicable." I understand that the Interstate Commerce Commission has issued no other order as to symbols and signs to be shown on the maps and profiles. If I am wrong in that undertanding, I would ask the President to kindly correct me.

The President:—The illustrated drawing accompanying this order shows some symbols different from those in the Manual of this Association. The Committee on Records and Accounts now presents to the Association a revision of the symbols heretofore published in the Manual, together with such additional symbols as it finds to be necessary.

Mr. Carpenter:—I understand that the symbols shown on the illustrative plans are not necessarily mandatory, but if that should be the case, that they are mandatory, I assume that the Committee will ascertain that fact. And so that there will be no conflict in any of these matters, I suggest that the Committee give the subject very careful attention as to any changes as to the conventional signs proposed.

Mr. Christian:—The symbols shown for pole wire lines is made mandatory by the Interstate Commerce Commission.

Mr. Carpenter:—If those are mandatory, then I will not mention further the criticisms on the symbols presented. There are additional symbols that will be required, particularly in connection with electrified track construction. I suggest that the Committee endeavor to include symbols for such construction.

Mr. Christian:—In regard to that point, your Committee on Signals and your Committee on Electricity have some symbols, and we will confer so that there will be only one symbol for each object.

Mr. C. P. Howard (Consulting Engineer):—I believe that the symbol for a curve on a profile shows the curve down underneath, does it not? I think, also, that the Interstate Commerce Commission symbols which have been recently submitted, in their profile show a solid line for tangent and dotted line for curve, which seems to me to be very much preferable. In the first place, the dotted line shows it to be a curve, and the letters "r" or "l" show whether it is to the right or to the left. In the second place, any topography you want to put on the profile will be distorted by the curved line. In the third place, I do not think there is any general unanimity of opinion as to the meaning of the symbol. In the case of a curve that bulges out to the right, some people think it is a curve to the right, and in the case of a curve which bulges to the left, it is a curve to the left. It seems to me the present symbol creates confusion and is not a good symbol. In my opinion the symbol of the solid line for the tangent and dotted lines for the curves, as adopted by the Interstate Commerce Commission, is better.

Mr. J. B. Jenkins (Baltimore & Ohio):—In view of the necessity of reproducing a great many maps for use by the Government for final records, it is essential, I think, to abandon the color scheme as far as possible. The Committee has proposed, under "hydrography," to show all such features in blue. A great many of these features are such as will appear on the ordinary record maps, and will have to be reproduced by photographic processes. There will be no confusion if those symbols are shown in black instead of blue, excepting those for canals and ditches, for which we could devise some other symbol. The Committee indicates that the relief features are to be shown in blue. That is a poor color for reproduction by photographic process, but brown reproduces very well and in the reproduction it shows a mellow line that is easily distinguishable from black lines on the original. I would suggest that the color for hydrography be made black and that for relief be made brown.

In view of the necessity of having these symbols adopted immediately, I would move that the Committee take note of all the suggestions and changes made at this meeting, and that the Committee be empowered to amend their recommended symbols as they may see fit, and that the amended symbols be considered adopted and authorized to be published in the Manual.

The President:—You have heard the motion that the substitutes offered by the Committee on Records and Accounts for insertion in the Manual be approved, it being understood that this Committee has power to make any changes which may seem proper in view of the discussion at this meeting.

Mr. Christian:—With reference to the second subject, this was taken up by your Committee last year jointly with the General Storekeepers' Association and the conclusions arrived at were submitted as information to the Association. We have not been able to do any better than last year, and your Committee moves that the conclusions be adopted as shown in the present report, namely, that conclusions 1, 2 and 3 be adopted and published in the Manual.

Mr. L. C. Fritch (Canadian Northern):—It would seem to me that a matter of that kind would be better if received as information instead of being published in the Manual. It is likely to be subject to continual change, and it seems to me it is just as valuable to us if it is a matter of information only.

The President:—The Committee states that they will be agreeable to that course.

Mr. Henry Lehn (New York Central):—In view of the fact that the Division of Statistics of the Interstate Commerce Commission have under consideration a new Operating Expense classification, which I understand they intend to put into effect at the beginning of the next fiscal year (July 1, 1914), I move that this subject (sub-dividing Operating Expense account No. 6, Interstate Commerce Commission, Roadway and Track) be referred back to the Committee for further consideration.

Mr. Christian:—Your Committee has received information from many of the States, and also blanks showing the information required by the State commissions; after these were all collected and analyzed, it was found that the majority of the States, with the exception of about nine, were using the blank forms of the Interstate Commerce Commission.

We can only report progress on this subject, and the Committee asks the views of the members and an interpretation of the subject assigned, whether it implies recommended changes in the forms prescribed by Federal or State Railway Commissions, or merely to make information available with reference to reports required by public service bodies.

The President:—I may say last year when this subject was assigned, that there were many standards in this country, but by the time the Committee makes its next report, there is likely to be only one standard so far as Federal regulation is concerned, and it seems to me the sub-

ject can very well go over and allow the Committee to bring in next year such a recommendation as its judgment suggests.

This Committee will have a very important work to do in the future, not that it has not had an important work to do in the past. It seems to me that we have been a little slow in taking up this question of engineering accounting, which has been referred to by Mr. Lehn, and it behooves this Association to get more information in connection with this question of accounting, so that during the next year I have no doubt that this Committee will consider not only engineering accounting, but these other questions as well.

The Committee is excused with the thanks of the Association.

DISCUSSION ON BALLAST.

(For Report, see pp. 961-1000.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BALLAST.

J. B. Berry.
W. M. Camp.
Chas. S. Churchill.
L. C. Fritch.
H. E. Hale.
J. B. Jenkins.
Hunter McDonald.
C. A. Morse.
Francis Lee Stuart.

The President:—We will now take up the report of the Committee on Ballast, which will be presented by Mr. H. E. Hale, Chairman.

Mr. H. E. Hale (Missouri Pacific):—The Association asked your Committee to revise the ballast section, particularly for use of sub-ballast and top-ballast. In working up this subject, the Committee presents drawings which appear on page 972 and following pages.

The Committee also submits ballast sections of various roads, and these are submitted for the purpose of giving the members of the Association sections which they are familiar with in various parts of the country and in case they are disposed to study the subject, we think these illustrations would be a great help to them. On page 988 are the proposed ballast sections. The Committee submits this rather in the form of a progress report without any definite recommendation, as we have not tried out these sections.

There is 24 in. of ballast under the tie, and this proposed section is a copy of the Baltimore & Ohio proposed section. The only other road which your Committee found that is figuring on 24 in. is the Pennsylvania Lines West, and their proposed section is at the top of page 977. The Committee wishes to call attention to the fact that the section on page 988 requires practically a 26-ft. roadbed, and on curves, on account of the elevation and the slope at the outside of the ballast, if the subgrade was made symmetrical, it would be nearly 30 ft. wide, but your Committee has recommended that the subgrade be not symmetrical, but that it be 15 ft. wide on the outside of curves and 11 ft. on the inside, which will vary with the degree of the curve. The above would be the dimensions for the maximum elevation.

The President:—The idea of the Committee is that this report will be before the membership the coming year and the Committee would like to have the result of the study of the members of the Association as it may be made during the year. Is there any discussion on the report?

Mr. W. M. Camp (Railway Review):—I will open discussion by asking a question. I notice in the top section, on page 988, there is a clear space of 2 ft. 9 in. beyond the toe of the ballast, for single track; also the same width for "Class A" double track. For "Class A" single track

on curves there is a difference between that and the "Class A" single track for tangent—it is 2 ft. on the outside of the curve and 16 in. on the inside.

I will ask how the Committee arrived at that dimension, and whether they consider it necessary to have it there for the purposes of roadbed stability. Did the Committee take into consideration, in arriving at that dimension, the bearing power of the soil we talked of the other day in discussing the report of the Roadway Committee?

Mr. Hale:—Your Committee considered those various points and we made the width of 26 ft. to keep the track as narrow as possible and have followed somewhat the precedent of the Baltimore & Ohio proposed section. The Committee has not tried this out and we do not know what the results will be.

The Committee does not wish to make any recommendation, but it is working with the Roadway Committee, and at our meetings we have discussed the question of the pressure on the roadway.

Mr. Camp:—What is the utility of the space? Is it intended to provide a sort of reservation against eventual wearing down of the embankment width?

Mr. Hale:—No, it adds to the stability of the track material. It has been found in gumbo spots, or soft spots, that a wide roadbed helps to hold the track stable. It is with that idea that the Committee wishes to get a substantial bank.

Mr. C. A. Morse (Chicago, Rock Island & Pacific):—The tendency of all our committees seems to be running to the ideal, rather than to the practicable. I think there are very few roads in the country that can possibly have Class A tracks, if Class A tracks require a ballast of this section. We do pretty well if we can get 10 or 12 in. While this may be ideal, I think the Committee report should be based on what the majority of the roads of the country can possibly use. I doubt if there is a road in the country that has 50 miles of track that has as much ballast as standard as the Committee has recommended. I think the Committee should recommend something that is practicable, something that we can use.

Mr. J. B. Jenkins (Baltimore & Ohio):—The ballast on the Cumberland Division of the Baltimore & Ohio will average 3 ft. deep for 50 miles. The depth of ballast is naturally increased in the ordinary course of maintenance if the track is kept in first-class condition under heavy traffic. As traffic increases and it becomes more difficult to maintain proper surface, ballast is added until the proper depth is reached.

Mr. Hale:—Your Committee felt there are many places where 12 in. is not enough. It is not supposed that every railroad in the United States will put 24 in. under the tie, but we do know some roads that are doing so. On page 963 we give you a photograph of what they are doing on the Pennsylvania Railroad. We also show you what they are doing on the Baltimore & Ohio. The tendency is to go to a ballast section of over 12 in. The Committee submits this as their idea of what would be first class.

Mr. L. C. Fritch (Canadian Northern):—I think the Committee is working along right lines. We all know with the dense traffic to-day, with the heavy wheel loads, we do not have sufficient ballast under our ties to maintain the track. The Committee should be slow, however, in making recommendations in this matter until exhaustive tests have been made which the Special Committee on Track Stresses will undertake. There have been some valuable tests made on the Pennsylvania Railroad which demonstrated that with certain densities of traffic and wheel loads at least 24 in. of ballast is necessary to maintain the track.

Mr. Francis Lee Stuart (Baltimore & Ohio):—We have on our road a section where we carry at times 2,500 loads a day, and in making our cuts and fills we are preparing them on the basis of having 2 ft. of ballast under the track. When we first lay our rails we will probably put 18 in. of ballast in the track and then leave the other 6 in. for the track force to raise in the course of their work. We do not suggest that section for all the roads in the country. However, the foundation of all good track is ballast, and the more ballast you get under your ties, the better returns you will get, if you keep within certain limits.

The President:—If there is no further discussion this matter will be left in the hands of the Committee for further consideration.

(Mr. Hale then read the conclusions on page 969, which were on motion adopted for publication in the Manual.)

Mr. Hale:—The Committee feels that the information given under the heading "Cleaning Ballast" is reliable, and shows that by the use of screens the cost of cleaning stone can be cut in half. The information in this report is given in detail, as are also the dimensions of the screen and how they can be obtained. In Appendix D is a contribution by Mr. Trench in which certain screens are mentioned. While these screens are patented and the report so states, the Committee felt the Association would like to have the information regardless of the patent, that the patent should not stand in the way of anything in the interest of economy.

Mr. Hale:—The Committee has had the subject of "Proper depth of ballast to produce uniform pressure on subgrade" in its charge for three years at least. Last year the Committee recommended a test be made which is outlined on page 971, but notwithstanding the efforts made to finance this test so far it has not been done. The test is a simple one and the Committee believes it is very advisable because it will be made under regular traffic conditions. We have the test of the Pennsylvania Railroad made at Altoona and the test of the German railways which are good, but they were not made under regular traffic conditions. The estimate of $3,000 as the expense of the test is very liberal, and was intentionally made so. As a matter of fact, a good many of the items, such as the stone, etc., will have to be purchased anyway by the railways.

Without some test of this sort the Committee feels it cannot go any further with this work, as it has exhausted every source of information available.

Mr. Stuart:—When I spoke a moment ago I did not understand that the 2 ft. of ballast is to be recommended for Class A tracks; I think that is an injustice to some railroads in the country. Twelve in. of ballast will make a satisfactory track for Class A operation and the 24 in. is only for use under special conditions.

Mr. J. B. Berry (Chicago, Rock Island & Pacific):—Your new Committee on Track Stresses is to be given $10,000 by some of the steel companies, and they expect to get $2,000 from the American Society of Civil Engineers. The Committee held a meeting yesterday and will organize for work in the near future. Among the things the Committee will follow up is the question of the amount of ballast under the tie. I think this Committee on Ballast can safely wait until they hear from this new Committee before they ask for any appropriation, as it is the intention of the Committee on Track Stresses to investigate the matter very thoroughly and they hope to report to the Association next year.

Mr. Hale:—We considered that. Of course we did not know what the new Committee would do, but the Committee on Ballast is unanimous in recommending this test. We feel it has been carefully outlined and studied for two years. No test has been suggested which will be as good as this one, on account of its being made under traffic conditions in the regular tracks in service, and we think it is very important to have it made.

The President:—The recommendation of this Committee is already before the Board of Direction and will be given most careful consideration.

Mr. L. C. Fritch:—We would like suggestions from the Committee or the convention at large in regard to the 1914 work for this Committee.

Mr. Hale:—Two subjects appear to be carried over. Your Committee recommended next year that an additional subject be added, namely, "The proper depth of ballast under various conditions of subgrade, etc." Where there is a soft bottom you need more ballast, and where there is good gravel, shale or rock subgrade very little ballast is needed. We think it would be a good plan to have definite recommendations made on that subject.

Mr. Chas. S. Churchill (Norfolk & Western):—I suggest that the Committee consider with this matter of depth of ballast, whether the use of sub-ballast is not just as good as a depth of stone ballast larger than 10 or 12 in. I believe they will find on investigation, among the various railroads, that some of them secure their total depth of ballast by adding a sub-ballast, such as cinder or slag, for example, which is not costly, and which simply raises the level of the roadbed, as shown in cut top of page 977. It forms a proper drainage and is purely a sub-ballast, not costing but a fraction as much as stone. Then on top of that is placed the regular ballast.

Mr. McDonald:—I would suggest that the Committee consider comparisons between the different kinds of limestone. I was recently very much surprised to find that limestone dust, which had passed through a No. 200 sieve, would give a tensile strength of 80 lbs. to the sq. in., after seven days, without any cement at all. I find in the use of some limestones, where the ballast is heavily tamped, and a large amount of dust accumulates under it, it forms a cement which clogs the drainage. I think the siliceous limestone is, therefore, preferable to one which has a high content of lime. I believe the matter is worth looking into.

The President:—The Committee is relieved with the thanks of the Association.

AMENDMENTS

AMENDMENTS TO COMMITTEE REPORTS.

REFERENCE TO AMENDMENTS MADE TO COMMITTEE REPORTS AT THE FIFTEENTH ANNUAL CONVENTION.

RULES AND ORGANIZATION.

(For Report, see pp. 65-70; discussion, pp. 1002-1007.)

Amend General Notice on page 66, by eliminating the words "of the road" at the end of the paragraph.

Amend Rule (10) under "General Rules for the Government of Employees of Construction Department" by adding the words "without permission" at the end of the paragraph.

Amend Rule (11) by substituting the words "the public" for "patrons of the road" at the end of the paragraph.

Amend Rule (2) under "Rules Governing Chiefs of Party" by eliminating the word "periodical" in the last line.

Amend Rule (4) by omitting the word "proper" in the first line.

Amend Rule (5) by inserting the word "instructions" after the word "prescribed" in the first line.

Amend Rule (6) to read as follows: "They must keep their parties supplied with instruments and material necessary for the efficient performance of their work, and see that these are properly cared for and used."

Eliminate Rule (10) and renumber (11) and (12) to be (10) and (11), respectively.

ROADWAY.

(For Report, see pp. 383-400; discussion, pp. 1031-1035.)

Amend conclusion (5) under "Tunnel Construction" by substituting the words "preferably not" for the word "never."

Insert the word "tonnage" before the word "train" in conclusion (b) under 'Tunnel Ventilation."

WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 401-406; discussion, pp. 1031-1035.)

Amend conclusion (1) by inserting the word "inner" before the word "guard" in the first line, and make the last line read "against direct impact with parts of moving equipment."

IRON AND STEEL STRUCTURES.

(For Report, see pp. 507-511; discussion, pp. 1045-1058.)

Amend conclusion (c) to read as follows:

"(c) Rail End Connections.—Rail ends should be connected by sliding sleeves or joint bars or by easer rails to carry wheels over the opening between the end of the bridge and the approach to the bridge."

MASONRY.

(For Report, see pp. 513-568; discussion, pp. 1059-1062.)

Amend conclusion (1) under "Disintegration of Concrete and Corrosion of Reinforcing Metal" to read as follows: "(1) Concrete to be exposed to the action of sea water, or alkali waters, or gases containing sulphur or in which reinforced metal is embedded should be dense, rich in Portland cement and allowed to harden under favorable conditions before such exposure."

Amend conclusion (2) to read: "Concrete to be in contact with alkali waters should be made with aggregates inert to the alkalis in the water."

BUILDINGS.

(For Report, see pp. 705-723; discussion, pp. 1099-1103.)

Amend first paragraph on page 710 by eliminating all words after the word "mainly" in the second line and add: "This report does not cover freight piers and deals only with single-story freight houses, where the mechanical handling of freight is not necessary." Also eliminate last line on page 714, reading: "This report does not cover freight piers."

On page 711, on the 26th line, add the following after the words "important terminals": "Many roads are building cars that are lower than the maximum figures given above, and each road in deciding the height of platform at the top of rail should take into consideration the size of car that will be used on its lines."

Amend fourth paragraph on page 711 to read as follows: "The distance from the center of the nearest track to the face of the platform or freight house should not be less than 5 ft. 9 in. to the base of the platform and 6 ft. to the base of the freight house from the center of the track."

TIES.

(For Report, see pp. 725-858; discussion, pp. 1121-1136.)

Amend conclusion (d) on page 727 to read as follows:

"(d) The width of the tie plate is an element to determine the mechanical wear of the tie. Tie plates less than 7 in. wide for use with softwood ties cut into the ties sufficiently in some cases to determine the life of the tie."

SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 859-904; discussion, pp. 1137-1150.)

Amend the specifications for road crossing signs on page 872 by eliminating all reference to creosoting.

Amend the specifications for road crossing signs on page 872 by amending the title to read "Wooden Crossing Signs."

PART 2

MONOGRAPHS.

GRADE REDUCTION PROBLEMS.

A STUDY OF GRADES ON A 130-MILE DIVISION.

POWER OF LOCOMOTIVE, SPEED AND TIME CURVES FOR TRAINS ON PRESENT AND PROPOSED GRADES; TOTAL TIME AND FUEL CONSUMPTION; MINIMUM COST IN FUEL AND TRAIN WAGES PER TON MILE; LIMIT OF ECONOMY IN WEIGHT OF TRAIN AND RATE OF GRADE; LENGTH OF DIVISION; MOMENTUM GRADES; GRADE OF CENTER OF GRAVITY FOR LONG TRAINS; STUDY OF OPERATING CONDITIONS.

By C. P. HOWARD, Consulting Engineer.

This study of grades was made in connection with a proposed reduction from a 0.6 per cent. maximum to 0.3 per cent. The results indicated, being such as could not have been determined by the usual more approximate methods, may be of interest to members of the Association who may be called on to make similar investigations.

In some respects it may be considered as a typical case. Not all the information desired was at hand. The Engineer is generally more or less limited as to time and facilities. He will not usually have at hand a train of locomotives and cars of the type to be used, loaded and weighed according to his desires, with dynamometer car and all other facilities for making tests, to say nothing of the various repetitions and comparisons necessary before results can be secured which may be considered as fairly average and representative. All he can do is to use all available information and calculate the rest from the best known data and formulas. But whether all the information desirable is at hand or not, such calculations must be made, and by all means should be as thorough and exact as possible. Every reasonable method of checking and verifying results should be employed. It is surely a penny-wise and pound-foolish policy which would refuse the time and money needed for proper investigations, at the time when such investigations should be made, and then enter hastily upon vast expenditures without knowing whether one-half the amount will ever be financially justifiable.

"The method herein described requires work and time, but it does away with the more or less 'scientific guess-work' with reference to the effect of distance, gradient, rise and fall, and curvature on the main accounts under 'conducting transportation' expenses. There will be less disappointment in the expectation of producing a decreased train mileage directly in proportion to the decreased total

resistance of trains on the controlling gradients. The actual economies realized will be much nearer the estimated economies than the average guess-work. The most important value is that it will, in many cases, save the waste of money in the investment of so-called improvements, which fail to realize a fair return on their cost. . . . . The time spent in preparing the tables and in making the calculations for any given lines is in itself a foundation for greater economies, and the cost of this time will bring abundant results." (A. K. Shurtleff, Bulletin 148, August, 1912, American Railway Engineering Association.)

DATA.

The tonnage, average loading of cars and characteristics of the locomotive were known. Profiles, maps and general information as to conditions of operation were available. The latest data of the Committee on Economics of Railway Location of the American Railway Engineering Association (except as otherwise noted) was used in connection with information and suggestions given by Mr. Shurtleff, Chairman of Committee, in Bulletin 148, August, 1912.

TONNAGE.

Tonnage statistics were carefully worked out, giving for dead freight for the preceding year:

Northbound, 2,600 trains, average 2,165 tons, total 5,630,000.

Southbound, 2,490 trains, average 1,271 tons, total 3,165,000.

Owing to the comparative lightness of movement in that direction, the reduction of southbound gradients was not considered.

POWER OF THE LOCOMOTIVE.

"Actual drawbar pull of the locomotive at various speeds should be used in making estimates with reference to economic value of various locations of line and grade, where such drawbar pull is known. Where not known, the drawbar pull should be calculated." (American Railway Engineering Association Manual, page 427.)

Not having this information, the drawbar pull at different speeds was calculated, using tables 1 to 7 inclusive (pp. 428 to 434 of Manual of American Railway Engineering Association.) In using these tables, as suggested at the time by Mr. Shurtleff, 0.85 lb. of superheated steam was assumed as equivalent in volume and pressure to one pound of saturated steam. Four thousand pounds of coal per hour was taken as the maximum consumption of coal fired per hour, except on one particularly long pull on the present grade. Here a consumption of 5,000 lbs. per hour for 25 minutes was assumed for the 2,700-ton train. Elsewhere for the 2,700-ton train,

and everywhere for the 4,000-ton train, the curve (a), Plate 1, two tons per hour for the engine when working, was assumed.

The locomotive, when running, is assumed to be working at its maximum cutoff for the given velocity, or to be drifting.

"The prevailing custom has been to calculate the power by using an arbitrary Mean Effective Pressure curve. With our modern locomotives, it has been impossible to realize the power calculated by this curve, particularly in sections of the country where the fuel is not of a very high thermal value." (Report of Committee on Economics of Railway Location, American Railway Engineering Association, Vol. 2, Part 1, 1910, page 632.) The curve (marked "M M") computed from Bulletin 1002 of the American Locomotive Company, is shown also on the diagram of Cylinder Tractive Power. It will be noted that curves (a) and (b) show a much smaller power for speeds over five miles an hour, especially curve (a), which with the exception above noted, was the one used in this investigation.

RESISTANCES.

From the cylinder tractive power are subtracted the locomotive and train resistances. The former were computed from table 7, page 434, of the Manual of the American Railway Engineering Association. Train resistances from 5 to 30 miles an hour were taken from table 3, page 35, Bulletin 43 of the University of Illinois, by Prof. Edward C. Schmidt. An addition of 3 lbs. per ton, equivalent to a 0.15 per cent. grade, was made for the starting resistance, diminishing down to that shown in table 3 (3.7 lbs. per ton for a 50-ton car) at 5 miles per hour. This low starting resistance was taken in view of the light grades, which would permit of utilizing the slack of the train to start one car at a time. For several miles after starting from the south yard, it was assumed the resistance would be somewhat higher, say 2 lbs. more per ton, diminishing as the journals warm up.

The increased starting resistance is not used in the tables and diagrams for retardation curves or any acceleration curves which do not start from zero speed.

ACCELERATION AND RETARDATION CURVES.

Cylinder tractive power at a given speed minus engine resistance gives the drawbar pull, P, on a level grade. From this, subtracting the train resistance, R, and dividing by the gross weight of train, engine, tender, cars, we get (P — R) per ton, the force available for overcoming grade resistance or accelerating from one speed to another.

Referring to the 2,700-ton train (P — R) per ton at eight miles per hour is 9.30, at nine miles per hour it is 8.34, the average between

the two speeds being 8.82. The distance, D, to accelerate on a level grade from one speed to another is $D = 70 (V_2^2 - V_1^2) \div 8.82 =$ 135 ft.

The same result is obtained by using a table of velocity heads (see Raymond's Elements of Railroad Engineering, page 186). Thus at 8 miles per hour the velocity head is 2.24, at nine miles an hour it is 2.84, the difference being 0.6 ft. Therefore, to accelerate from 8 to 9 miles an hour is equivalent to climbing a grade to an elevation of 0.6 ft.

The average (P—R) available for acceleration is, as above noted, 8.82 lbs. per ton. This is the force required to climb a 0.441 per cent. grade.

Therefore, dividing the difference in velocity head, 0.6, by the equivalent grade, 0.441, we get 1.36 stations as the distance to accelerate from 8 to 9 miles per hour on a level grade. If the grade of track were + 0.2 per cent. we would have a net force for acceleration equivalent to a grade of $0.441 - 0.2 = 0.241$; and it would take $0.6 \div 0.241 = 2.48$ stations to accelerate from 8 to 9 miles per hour. On a + 0.6 per cent. grade, the accelerating force would be minus; that is, we have a *retarding* force and a net equivalent grade of $(0.441 - 0.6) = -0.159$. Then the distance required to retard from one speed to the other, i. e., from 9 to 8 miles per hour, would be $0.6 \div 0.159 = 3.77$ stations.

The tables and diagrams of acceleration and retardation have been calculated and platted by this method, using the table of velocity heads.

Accelerations and retardations with the engine drifting have to consider only engine and train resistances and the accelerating or retarding force due to grade. For simplicity in the "drifting" tables, the train resistance is taken as constant according to the American Railway Engineering Association formula, $R = 2.2T + 122$ $C = 4.64$ lbs. per ton for a 50-ton car. The engine resistance is also taken as constant in the "drifting" tables, neglecting the slight variation in the wind or head end resistance, and is 2,900 lbs. for the given engine.

Train resistances were computed for a 50-ton weight of car and load. The average for the northbound trains is now about 46 tons per car and is probably increasing.

FUEL.

The quantity of steam produced for any given rate of coal consumption per square foot of heating surface is taken as directly proportional to the B. T. U. or thermal value of the coal (see table 1, page 428, Manual American Railway Engineering Association.) The coal used at present has a thermal value of approximately 12,900 B. T. U. Ninety per cent. of this value or 11,600 B. T. U. was used. Mr. Shurtleff, Chairman of Committee, and author of the

tables in the Manual, gives records of tests by the U. S. Geological Survey, showing that the average car samples run about 90 per cent. of the air-dried mine samples, and states that he generally uses about this percentage in his calculations.

The cost of the fuel on the tender was estimated at $1.50 per ton.

PROFILE.

The profile was platted on plate "A" paper; 20 ft. to the inch vertically, and 2,000 ft. to the inch horizontally. This scale was convenient for the purpose, but for steeper grades a vertical scale of 30 or 40 ft. to the inch might be used.

SPEED CURVES.

From the acceleration and retardation diagrams the speed curves were platted on the profile from the south yard to the north end of division, using a scale of one inch equal to 20 miles per hour. Time was scaled from the speed curves of the profile, using a small scale on a slip of profile paper, representing the time in minutes and decimals required to travel 1,000 ft. for corresponding speeds on the profile. Within the limits of the south yard, both the time and the distance were approximated roughly, assuming that the engine would be working about one-third the time or running at about one-third its maximum speed. From an inspection of the telegraphic train sheets for three days, October 1, 2 and 3, 1912, it was concluded to assume the train as making five stops. These stops were estimated at 45 minutes each, or three hours and 45 minutes for stops between the south yard and the north end of division.

The speed curves are similar to those shown on page 1327 of Part 2, Vol. 11 of Proceedings of American Railway Engineering Association, accompanying an article by John D. Isaacs and E. E. Adams; except that the sharp angles in the curves occurring at grade changes have been rounded off to more nearly approximate actual conditions. The angles in the speed line would not really exist. The center of gravity of long trains does not really follow the grade at these angles. A 4,000-ton train of 50-ton cars would be about 3,200 ft. long. With the center of train at the summit intersection of two +0.3 per cent. grades, the ends of train would be nearly five feet lower, and the center of gravity about 2½ ft. lower, if the cars are uniformly loaded. With heavier grades, the difference would be greater for the same length of train. At two places on the profile, proposed revisions Nos. 10 and 11, the grade of center of gravity was platted approximately. It will be noted this makes quite an important change in the resultant grade line. At proposed revision No. 10, it does not differ greatly from the proposed 0.3 per cent. grade revision, indicating at both places in connection with the speed

curves that, as a question of limiting grades, the proposed 0.3 per cent. revision is unnecessary.

To plat this gravity grade line exactly it would be necessary to lay off the length of train on profile, divide it up into a number of lengths, preferably of equal weight, and consider it as being moved along the profile, computing the rise or fall of each portion for every 100 ft., or say every 500 ft., as it moves. Averaging these results will give the rise or fall of the center of gravity of train for each interval, and from this the gravity grade line may be platted. In this instance, as a convenient approximation, the train was taken as 3,000 feet long, of uniform weight per foot of length. The motion of the center point was averaged with each end and the result platted as shown.

The speed line for 4,000-ton train indicates that a number of proposed revisions could be dispensed with.

TIME AND FUEL CONSUMPTION.

Table 8 shows the time working, drifting and standing; total time and fuel consumption.

For 2,700-ton train on present grade, the time as estimated is:

	Hours	Minutes
Through south yard	0	45
Thence to north end of division	7	43
Standing at station—5 stops of ¾ hr. each	3	45
Total 129.75 miles	12	13

Average speed between stations north of south yard, 16.1 miles per hour.

Fuel consumed, 14.94 tons, which checks with the Superintendent's figures. It was estimated or assumed by him at 15 tons.

For the 4,000-ton train running on revised grade, time estimated is:

	Hours	Minutes
Through south yard	1	0
Thence to north end of division	9	22
Standing at stations, 5 stops of ¾ hr. each	3	45
Total 129.75 miles	14	07

Fuel consumed, 19.1 tons.

The 4,000-ton train takes 1 hour and 54 minutes longer between stations. The delays at stations are assumed to be the same. With the diminished number of trains on the road better hours might be chosen for the run, but the train is on the road longer and might have more passing points.

The total time is increased 15½ per cent. and the fuel consumption 27.8 per cent. The tax on the fireman will therefore be greater.

Before assuming the 4,000-ton train can make it in fourteen hours, it was suggested that it might be well to find out by test whether the 2,700-ton train (50-ton cars) could and should make it in 12. This would be valuable as a check. If ascertained to be entirely practicable, then we may with greater confidence assume that the heavy train will realize its expected performance on the reduced grades. Twelve hours for the 2,700-ton train is somewhat better than might be expected, judging from what we understand has been the experience on this district heretofore; but recent improvements in the quality of fuel and the elimination of delay from doubling at one point may make it practicable.

Messrs. Isaacs and Adams, in article above noted, estimate one-half hour per stop, or 2½ hours for the five stops. Mr. Shurtleff, in Bulletin 148, American Railway Engineering Association, estimates one hour for water, coal, orders, etc., plus 15 minutes for each meeting and passing point, or 2 hours and 15 minutes for the five stops. If time lost at stops could be reduced to figures in Mr. Isaacs' paper, we would save 1 hour 15 minutes. By Mr. Shurtleff's figures we would save 1½ hours.

If we allowed thirteen hours for the 2,700-ton train, 15½ per cent. proportionate increase would make 15 hours for the 4,000-ton train, a condition which would bring up the question of subdividing the district. Taking a station near the one-third point, 43.5 miles from the north end, we would have approximately 10 hours from the south end and a turn-around of 5 hours each way from the north end, plus the time lost at the subdivision point. The question of time on the road being then of less importance, trains might be loaded heavier, say, up to 4,500 tons or more when necessary. This would ease up things and give more latitude in operation, the cost in train wages and fuel per ton, however, remaining about the same.

Some serious objections to the turn-around which may be mentioned are the necessary outlay for tracks and plant at the sub-terminal, and the delay of cars. Taking the total movement we have:

Northbound 2,600 trains, 47 cars each........	122,200 cars
Southbound 2,490 trains, 47 cars each........	117,000 cars
Total cars per year over division	239,200

If we assume an average delay at the sub-division point of two hours, estimating at 45 cents per day per car, we have:

239,200 cars at 3¾c $8,970

Which, capitalized at 5 per cent., amounts to....$179,000

We might assume roughly the following expenditure for the sub-terminal:

10 miles sidetrack at $12,000	$120,000
10 stall roundhouse at $3,000	30,000
2 cinder pits at $2,500	5,000
1 crane	6,000
1 coal chute	10,000
Water pipes and pen stocks	10,000
Air plant	2,000
Total	183,000
Adding the above	179,000
Total against subdivision	$362,000

All of which would point to the advantage of getting the trains over the division in a day if possible.

MECHANICAL STOKER.

One way to reduce or eliminate the delay for heavy trains would be to increase the rate of coal consumption by the engine when working. We have before us a blueprint of a Mikado engine with curve showing tractive power at various speeds and fuel consumption of 7,000 lbs. per hour, this engine being equipped with a Street stoker. I understand, however, the amount of coal was not measured. The heating surface of the engine is about the same as the one considered in this estimate. On the lighter train we estimate 15 tons fired for the trip and 19.1 tons for the heavy train. The fireman on the 2,700-ton train, north of the south yard, shovels with engine working:

5.22 hours	at 4,000 lbs.	10.44 tons
0.42 hours	at 5,000 lbs.	1.05 tons
Total 5.64	4,080 lbs.	11.49 tons

which is equivalent to 5¾ hours at 4,000 lbs. per hour.

On the 4,000-ton train he shovels 7.88 hours at the same rate. That is, he has to keep up his maximum rate more than two hours or 37 per cent. longer. A mechanical stoker, which would make this result certain and easy of accomplishment, might solve the problem without increasing the rate of consumption. We have not sufficient data to pass on the relative economy of these stokers, but the regularity and freedom from exposure to air every time the door is opened may be important considerations.

The speed of the 2,700-ton train between stations north of the south yard, is 16.1 miles per hour against 13.3 for the 4,000-ton train; or 21 per cent. greater. The amount of steam produced per hour and consequent speed increases with the rate of coal consumption, but not in the same ratio.

Referring to tables in the Manual of American Railway Engineering

Association, taking 85 per cent. of quantities in tables 2 and 4 for superheated steam; engine resistance 2,900 lbs.; train resistance 4,000 x 4.3 = 17,200 lbs., we find that 5,900 lbs. coal per hour will be required to attain a speed of 16.1 M. P. H. on a 0.124 per cent. grade; which is the equivalent grade of the 4,000-ton train at 13.3 M. P. H. and 2 tons per hour coal consumption.

That is, 21 per cent. increase in speed requires an increase in the rate of coal consumption per hour of 47½ per cent., and the amount of coal consumed for a given *distance* increases (1.475 ÷ 1.21 = 1.22), 22 per cent., or almost directly as the speed.

As the coal consumed by the engine of 4,000-ton train on the whole division, while working is 16.4 tons, we conclude that approximately 16.4 x 22 per cent. = 3.6 tons, would be needed to make this increase in speed. At $1.50 per ton this amounts to $5.40; which is a rather expensive method of saving 2 hours in train wages, were that the only consideration. At $1.86 per hour, train wages for 1 hour and 54 minutes amounts to $3.53. If time is estimated at 45 cents per day per car we would have 80 cars at 3.6 cents = $2.88, which, added to $3.53 in train wages, amounts to $6.41, against $5.40 for the extra fuel.

It was hoped, however, that by careful management, cutting down the length of stops, etc., with good fuel, that with or without the addition of mechanical stokers the 4,000-ton train might be handled in one day's run at something like the calculated time and fuel consumption, and on this assumption the estimates of savings were based.

TRAINS WEIGHING MORE THAN 4,000 TONS. TABLE 9.

Having estimated the time, speed and fuel consumption for a 2,700-ton train, which is taken as the maximum for the present grade, and also for a train of 4,000 tons, the results of any heavier loading may be considered after the method outlined by Mr. Shurtleff on page 13, Bulletin 148, Vol. 14, August, 1912, of the American Railway Engineering Association.

The average velocity of the locomotive of the 4,000-ton train, while working north of the south yard, is 13.07 miles per hour. At this velocity and loading (P — R) is 2.6 lbs. per ton of gross weight of train, equivalent to a 0.13 per cent. grade. This is the grade on which the given speed may be maintained and will be considered as the equivalent or average grade of resistances for that part of the district (north of the south yard) on which the engine is working, and not drifting (103 miles out of 124.26). We assume that for heavier trains the engine will be working over the same distance. On this grade we compute the weight of trains that can maintain a speed of 12, 11 and 10 miles per hour; namely, 4,300, 4,610 and 4,930 tons, as shown in Columns 2 and 4, Table 9. The calculated speed on a + 0.3 per cent. grade; the fuel consumption, time, tons per engine hour, etc., are shown in succeeding columns. In Column 15 it will be noted that the 4,300-ton train has the same fuel consumption per ton of train, with only 2 per cent. (Col. 14)

increase per hour in the efficiency of engine and crew, measured in ton miles. The time has been increased ¾ hours or 5½ per cent. and the weight of train 7½ per cent. Similarly for the 4,610-ton train, as compared with the 4,000-ton train, we have an increase of train weight of 15 per cent., an increase in efficiency of engine and crew of 2½ per cent. and an increase in fuel consumption per ton of ½ of 1 per cent.

For the 4,930-ton train, which could maintain a speed of only 3.82 miles per hour on a + 0.3 per cent. grade, we have an increase in weight of train of 23 per cent., increase in efficiency of engine and crew of 4 per cent., increase in fuel consumption per ton of train of 2.4 per cent.

The fuel consumption per *ton*, it will be noted, remains practically the same and there is very little increase in the efficiency of work done by engine and crew, as measured in ton miles per hour. When the trouble of starting heavy trains from the south yard, additional length of sidings, loss of time of cars, increase in cost of grade reduction to more nearly approximate a 0.3 per cent. grade, and the probable expense of subdividing the divisions are considered, there are no apparent advantages in a greater loading than 4,000 tons. With a shorter division, using a turn-around, there might be a certain amount of benefit in the greater latitude of operation; allowing trains to be increased considerably whenever it is convenient to do so, but with no resultant economy in fuel and very little in the efficiency of engine and crew as measured in ton miles.

SAVING IN OPERATING EXPENSES.

Passenger trains would not be appreciably affected by the changes proposed, and it is assumed that fast freight and local freight trains would not be. The time table gives a rating of 1,900 tons for fast freight trains with the given engine. As this engine could pull about 2,500 tons of 38-ton cars over the steepest grade, it is not apparent that the present grades limit these trains. Similarly for southbound traffic as above noted. Southbound grades are light enough to accommodate the increased length of trains, considering the lighter tonnage.

NORTHBOUND MOVEMENT—DEAD FREIGHT.

The present annual tonnage is 2,600 trains, average weight 2,165 tons, total weight 5,630,000. With the proposed proportionate increase in loading from 2,700 tons to 4,000 we would have the average weight per train, 3,207 tons, number of trains, northbound, 1,755. The number of trains southbound is now somewhat less, being 2,490 against 2,600 northbound. We assume them to be the same for the reduced grades, as there will be less surplus power to admit of variation in length of trains.

We would then have $1,755 \times 2 = 3,510$ trains, against $2,600 + 2,490 = 5,090$ per year, a saving of 1,580 trains per year. Multiplying this by 129, the average length between terminal yards, we have $1,580 \times 129 = 203,800$

train miles per annum. These figures take into consideration the reduced tonnage of the average train as compared with the calculated maximum, and show a greater saving than would be obtained by taking the figures for the maximum train. The figures for fuel consumption have been based on the maximum train, and it seems not improbable that the operating efficiency would be less for the heavier train, requiring a longer time to get over the division. Consequently we use only the figures for the calculated performance of maximum trains from which to compute savings in operation:

$2 \times 5{,}630{,}000 \div 2{,}700 = 4{,}170$ trains per annum.
$2 \times 5{,}630{,}000 \div 4{,}000 = 2{,}815$ trains per annum.

Computed saving. 1,355 trains per annum.
$1{,}355 \times 129 = 174{,}800$ train miles per annum.

MAINTENANCE OF WAY AND STRUCTURES.

By report of Committee on Economics of Railway Location, presented March 18, 1912 (referred back to Committee), these expenses were based on equivalent ton miles, in estimating which the weight of freight engines is multiplied by two. As train tonnage would be the same, we have for additional equivalent tons per mile of road, $2 \times 1{,}355 \times 227$ (weight of engine and tender) $= 615{,}000$ tons.

In a former report on another division of the same road, expense of Maintenance of Way and Structures was estimated at $620 per mile plus $105 per mile per million equivalent ton miles, this being understood to apply only to the main line between division terminals, not including sidetracks. The $105 per million equivalent ton miles is the only part which affects the estimate, viz.:

0.615 million equivalent tons at $105 = $64.60 per mile.
129 miles at $64.60 = $8,330 per year.

MAINTENANCE OF EQUIPMENT.

The car miles are the same, and we have only to consider freight engines. From the annual report of the road we have:

Freight locomotives, road, repairs	$2,421,527
Freight locomotives, depreciation	222,183
Total for these items (a)	$2,643,710
Also—	
Revenue freight train miles	18,127,028
Helping and light freight locomotive miles	568,353
Total for these items (b)	18,695,381

Dividing (a) by (b), we have 14.1 cents per freight engine mile.

Also from annual report:
Shop, machinery and tools (c)................................$322,881
And total revenue service miles, excluding switching (d)......32,305,087

Dividing (c) by (d), we have 1 cent per engine mile. Total, 14.1 cents + 1 cent = 15.1 cents, or, in round numbers, 15 cents.

The freight train miles will be reduced from 4,170 to 2,815, a reduction of 32⅛ per cent. The engine *hours*, however (see table 9), will be reduced only 22 per cent. Again if we proportioned these expenses to work done by the engine as measured by fuel consumption, we would have a reduction in these items of only 14 per cent. The Mikado is a heavy engine, and expenses would probably run above the average. We shall assume them as being in proportion to the engine *hours*, or $22 \div 32.5 \times \$0.15 = 10$ cents per engine mile.

We have then for saving in maintenance of equipment 174,800 engine miles at 10 cents = $17,500 per annum.

TRANSPORTATION EXPENSES.

From annual report:

Engine house men—freight, $500,883.

There seems to be no particular reason in this case why this item should not vary with the number of freight engine miles. Dividing by (b) above we have 2.68 cents per engine mile, making a saving of $174{,}800 \times 0.0268 = \$4{,}680$ per annum.

In table 9 we have 11.07 lbs. coal per ton of train for present operation, and 9.55 for 4,000-ton train. The saving is $11.07 - 9.55 = 1.52$ lb. per ton of train, or 13.7 per cent.

We check the Superintendent's figure 15 tons, as to fuel consumption for northbound trains, and shall assume his figure of nine tons for present southbound trains as close enough, making an average both ways of 12 tons.

The total saving will be:

4,170 trains $\times 12 \times 0.137 = 6{,}850$ tons
6,850 tons at $\$1.50 = \$10{,}300$ per year

Items of annual report which we take as varying with the fuel consumption are:

Engine house supplies—freight	$ 52,541
Water for freight locomotives...............	158,712
Lubricants for freight locomotives...........	60,644
Other supplies for freight locomotives......	49,031
	$320,928

Dividing this by (b) as before, we have 1.7 cent per freight train mile; and, as the fuel reduces 13.7 per cent. we have $4170 \times 129 \times .017 \times .137 = \$1{,}250$ per annum.

Engine and trainmen's wages will be estimated per hour, ten hours being:

1 Conductor	$ 4.18
2 Brakemen	5.56
1 Engineman	5.15
1 Fireman (Mikado)	3.75
Total	$18.64, or $1.86 per hr.

We have for estimated operation:

Present grade (2,700-ton train) $4,170 \times 12.21 = 50,900$ hours
Reduced grade (4,000-ton train) $2,815 \times 14.11 = 39,700$ hours

Time saved	11,200 hours
11,200 hours at $1.86	$20,800 per annum

EQUIPMENT RELEASED.

The capitalized cost of an engine in service is considered as follows:

(1) The first cost of locomotive.

(2) The capitalized value of the annual expenditure for repairs.

(3) The amount of a sinking fund, whether actually set aside or not, which at compound interest will be sufficient to pay for renewals indefinitely.

We have already estimated the cost of (2) repairs and (3) the annual expense of depreciation or sinking fund. It now remains to estimate (1) the first cost of locomotives released from service.

It is estimated that each engine will make an average of about one trip of 129 miles per day, with an average of three engines (out of 24) in the shop per day; or say 125 miles per day, with 10 per cent. of its time in the shop, representing an average performance of 113 miles per day = 41,250 miles per year.

It was estimated above that there would be an annual saving for the 4,000-ton train of 174,800 train miles. Reducing this proportionately to allow for the increased time of the heavier train, we would have an equivalent saving in train miles of $174,800 \times \frac{22}{32.5} =$ 117,800 train miles, which divided by 41,250 = 2.85 engines released.

2.85 engines at $20,000	$57,000
Annual saving, 5 per cent. of 57,000	2,800

TOTAL SAVING IN OPERATION.

Maintenance of way and structures		$ 8,300
Maintenance of equipment		17,500
Transportation expenses:		
Engine house men	$ 4,700	
Fuel	10,300	
Water and supplies	1,200	
Train wages	20,800	37,000
Total annual saving in operating expenses		$62,800
Equipment released, interest on cost		2,800
Total estimated saving per year		$65,600

which capitalized at 5 per cent. amounts to $1,312,000. Note that this saving is equivalent to 37.5 cents per train mile eliminated.

ESTIMATES OF COST OF GRADE REDUCTION.

Estimates were made of the cost of reducing grades to a 0.3 per cent. on 16 different parts or "sections" of the district. It was recommended that for purposes of grade reduction, work be done only on sections 1, 9, 13, 15 and a part of section 3.

The estimated cost of reducing grades to a 0.3 per cent. on those sections where grade reduction was considered necessary was much less than the estimated savings. Improvements on other sections, where the speed curves clearly indicated that the grades would ordinarily give no trouble, were not recommended. If conditions arise which make it necessary for trains to stop on these short grades often enough to cause any appreciable expense, revisions at such points may be made.

THE MOST ECONOMICAL GRADIENT.

As elsewhere noted, the 4,000-ton train can be handled on a 0.4 per cent. grade at a maintained speed of about 4 2/3 miles per hour without the use of momentum. In Bulletin 148, August, 1912, American Railway Engineering Association, page 10, Mr. Shurtleff says: "The locomotive is figured on the maximum at 5 M.P.H. Formerly, in calculations of this character, 10 M. P. H. was the minimum velocity assumed, but common practice in everyday work for dead freight will load the locomotive down to this low velocity on the ruling grades wherever there is sufficient amount of lighter gradients on the district, so that the train can cover the same without overtime, unless the traffic be so dense as to call for the stopping and starting of trains on the ruling gradients, due to block signals being against them."

It was recommended that the 0.3 per cent. grade be used on section No. 1 and at one other point. It was also suggested that on certain other sections, estimates be made of the cost of reducing to 0.375 per cent. and 0.35 per cent. against traffic.

A 0.375 per cent. grade would give a maintained speed for the 4,000-ton train of 5.4 M. P. H. and a 0.35 a speed of 5.9 M. P. H. Of course the 0.3 per cent. grade would have some advantage as giving a greater leeway, and as making possible the handling of heavier trains in case this should at times be desirable.

Taking the monthly average, there is little variation in the weight of northbound trains over different parts of the division. The difference is probably much greater from day to day. For instance, the engine may haul 3,000 tons over one-half the division, and 2,000 over the other, or vice versa; dropping or adding on cars from time to time. Similarly after grades are reduced, it may at times be convenient to haul 3,500 over one part of the division and 4,500 over the other, the average weight of train per mile remaining the same, or about 4,000 tons. Were the grades such as to limit the train to 4,000 tons all over the division, this would then represent the maximum train and any variation or irregularity in the length of train would tend to reduce the average *below* 4,000 tons. In other words with a lighter grade, cars could be put on and off at pleasure, the only limit being one of time, depending more or less on the average loading and total work done by the locomotive.

It is possible that this feature of operation, regardless of other considerations, would make it desirable to reduce to 0.3 per cent. This investigation was not carried far enough to estimate the saving that might result from such a reduction and its consequent greater latitude in operation. The figures indicate a substantial saving for a reduction to a grade which would permit the comfortable handling of a 4,000-ton train—say 0.375 or 0.35 per cent. A further study along these lines to determine the advantages of a reduction to 0.3 per cent. or below might be amply justified; aside from its general interest in throwing light on conditions of operation which affect the problem of maximum economy in grades.

In this particular problem an approximate test of the correctness of calculations as to speed, time and fuel consumption could be made for the 4,000, as well as the 2,700-ton train. For the former it would be necessary to use a helping engine at points where the present grade is too steep. But as these stretches are not long, the performance could be noted on the rest of the division, and corrections made for time lost attaching and detaching the helping engine.

Appendix.

The following formula may be of use in connection with table (2) or with table (3), the latter to be used only in case of an isolated short and steep grade, where exceptional work on the part of the fireman may be expected.

Equation (1) is used to determine weight of train that can be hauled on a given grade at a given maintained speed; equation (2) to find the maintained speed at which a given train on a given grade can be hauled.

$$T = \frac{P - 20EG}{r + 20G} \qquad (1)$$

Where P = Drawbar pull in pounds of engine on a level grade, i. e., the cylinder tractive power minus the engine resistances. It is given in column 4 of table (2) or (3), and varies with the speed.

Where G = Per cent. of grade.

r = Resistance in pounds per ton of train behind the tender.

T = Weight of train behind tender in tons.

E = Weight of engine and tender.

Another form of the formula is:

$$P = (r + 20\,G)T + 20\,EG \qquad (2)$$

If any speed is assumed and T is to be calculated P may be found from column 4 of table (2) or (3); r may be taken from page 35, Bulletin No. 43, University of Illinois (copies may be obtained from Prof. Edward C. Schmidt at Urbana, Illinois). Or if the American Railway Engineering Association formula be used which gives higher resistances than those in Bulletin 43 of University of Illinois, reference may be made to the Manual of American Railway Engineering Association giving the flat rule, $r = 2.2\ T + 122\ C$. In view of the higher resistances at starting Prof. Schmidt omitted from his data all tests taken during the first 10 miles of run.

20G is the grade resistance in pounds per ton of train and 20EG is the total grade resistance of engine and tender $= 227 \times 20G$ for the locomotive used.

P, G and r being known, T may be found from equation (1).

If the grade, G, and weight of train, T, are known, r must be taken by trial from Bulletin 43, (if American Railway Engineering Association formula is used it may be ascertained at once from the weight per car), and P found from equation (2). The corresponding speed may then be found by interpolation from table (2) or (3). But as the resistance, r, varies with the speed, the value of r must be corrected for the proper speed, and a second, and possibly third calculation may be necessary if it is desired to calculate the speed with great accuracy.

TABLE 1.

.Engine ———. A. R. E. Assn. Formulas. Maximum Coal Consumption 4,000 lbs. per hour. B. T. U. 11,600. Heating Surface 4,070 sq. ft. Steam Pressure 175 lbs. Cyl. 27'' x 30'', Drivers, 63'', Schmidt Superheater. Superheated steam taken as 85% weight of equivalent saturated steam. Lbs. coal per sq. ft. heating surface=0.983. By table 1, p. 428, Manual A. R. E. Assn. Lbs. steam per lb. coal=5.69. Then 4000 x 5.69=22,760 lbs. steam per hour. Taking 85% of quantity in table 2 on account superheater

0.85 x 1.664 x 2.5 x 4=14.14=weight of steam per rev. drivers
22,760÷14.14=1,610 revs. per hr. at full cutoff
=26.83 revs. per min.
= 5.03 M. P. H.
=Velocity "M"

I. H. P. at "M" velocity=22,760÷(38.3x0.85x1.017)=687.4
C. T. P. at "M" velocity=687.4 x 375÷5.03=51,240

Cylinder Tractive Power from starting up to 35 M. P. H. calculated by table 5 of Manual.

Velocity		Per Cent. of "M" CTP	C. T. P.	Velocity		Per Cent. of "M" CTP	C. T. P.	Velocity		Per Cent. of "M" CTP	C. T. P.
Per Cent. of "M"	Miles per hour			Per Cent. of "M"	Miles per hour			Per Cent. of "M"	Miles per hour		
Start	Start	106.00	54,300	3.2	16.10	49.91	25,600	5.8	29.17	26.30	13,500
0.5	2.51	103.00	52,800	3.4	17.10	47.24	24,200	6.0	30.18	25.34	13,000
1.0	5.03	100.00	51,200	3.6	18.11	44.75	22,900	6.2	31.19	24.44	12,500
1.2	6.04	91.53	46,900	3.8	19.11	42.39	21,700	6.4	32.19	23.59	12,100
1.4	7.04	84.46	43,300	4.0	20.12	40.10	20,500	6.6	33.20	22.79	11,700
1.6	8.05	78.55	40,200	4.2	21.13	37.96	19,400	6.8	34.20	22.06	11,300
1.8	9.05	73.60	37,700	4.4	22.13	36.03	18,400	7.0	35.21	21.38	10,950
2.0	10.06	69.37	35,600	4.6	23.14	34.26	17,500				
2.2	11.07	65.67	33,600	4.8	24.14	32.59	16,700				
2.4	12.07	62.22	31,800	5.0	25.15	31.11	15,900				
2.6	13.08	58.92	30,200	5.2	26.16	29.75	15,200				
2.8	14.08	55.78	28,600	5.4	27.16	28.48	14,600				
3.0	15.09	52.78	27,000	5.6	28.17	27.33	14,000				

TABLE 2.

Acceleration on a level grade. Weight of train, 54 cars, 50 tons each=2700 tons; engine and tender, 227 tons, total weight of train 2927 tons. Corrected for Superheater. Using A. R. E. Assn. Formulas, 11,600 BTU, 4,000 lbs. of coal fired per hour. Train resistance above 5 miles per hour taken from U. of I. Bulletin No. 43, page 35.

Columns (2) to (6) inclusive in units of 100 pounds.

Velocity head increased by 4.63% to allow for rotation of wheels (see p. 186, Raymond's "Railroad Engineering").

1	2	3	4	5	6	7	8	9	10	11	12	
Velocity	C. T. P.	Engine Resistance	D. B. Pull (P)	Train Resist. (R)	P—R	P—R Per Ton	Equiv. Grade %	Velocity Head	Diff. in Vel. Hd.	Dist. to Accelerate in stations	Total Dist. in Stations	Remarks
Start	543	28	515	181	334	11.40	....	0.00	....	....	....	Train Resistance (R) at starting from ordinary short stops at stations taken as 3 lbs. per ton more than that at 5 M. P. H. Average 2 successive values in Col. (7) and divide by 20 to get value in Col. (8). Col. (10) divided by (8) equals (11).
1	537	28	509	165	344	11.76	.579	0.03	.03	.05	.05	
2	531	28	503	149	354	12.10	.596	0.14	.11	.18	.23	
3	524	28	496	132	364	12.44	.614	0.31	.17	.28	.51	
4	518	28	490	116	374	12.78	.630	0.56	.25	.40	.91	
5	512	28	484	100	384	13.12	.648	0.87	.31	.48	1.39	
6	471	28	443	103	340	11.62	.618	1.26	.39	.63	2.02	
7	435	28	407	104	303	10.35	.549	1.72	.46	.84	2.86	
8	405	28	377	105	272	9.30	.491	2.24	.52	1.06	3.92	
9	378	28	350	106	244	8.34	.441	2.84	.60	1.36	5.28	
10	357	28	329	107	222	7.58	.398	3.50	.66	1.66	6.94	
11	338	28	310	108	202	6.90	.364	4.24	.74	2.03	8.97	
12	320	28	292	109	183	6.26	.329	5.04	.80	2.43	11.40	
13	303	28	275	111	164	5.61	.296	5.91	.87	2.94	14.34	
14	287	28	259	113	146	4.99	.265	6.86	.95	3.58	17.92	
15	272	28	244	114	130	4.44	.234	7.87	1.01	4.32	22.24	
16	257	29	228	116	112	3.83	.207	8.96	1.09	5.26	27.50	
17	244	29	215	119	96	3.28	.177	10.11	1.15	6.50	34.00	
18	231	29	202	121	81	2.76	.151	11.34	1.23	8.14	42.14	
19	219	29	190	122	68	2.32	.127	12.64	1.30	10.23	52.37	
20	207	29	178	124	54	1.84	.106	14.00	1.36	12.94	65.31	
21	196	29	167	128	39	1.33	.079	15.44	1.44	18.24	83.55	
22	185	29	156	130	26	.89	.050	16.94	1.50	30.00	113.55	
23	176	29	147	132	15	.51	.035	18.52	1.58	45.20	158.75	
24	168	29	139	133	6	.20	.020	20.16	1.64	82.00	240.75	
24.6	....	....	....	....	0	.00	.005	21.18	1.02	204.00	444.75	
25	160	29	131	135	4	-.14	-.0034	21.88	.70	....	....	
26	153	30	123	138	-15	-.51	-.016	23.66	1.78	....	....	
27	147	30	117	140	-23	-.79	-.032	25.52	1.86	....	....	
28	141	30	111	154	-43	-1.47	-.056	27.44	1.92	....	....	

TABLE 3.

Acceleration on a level grade. Using A. R. E. Assn. Formulas, 11,600 BTU, 5000 lbs. coal per hour, corrected for Superheater. Columns (2)-(6) in units of 100 lbs.; weight of train 2700 tons; 54 cars, 50 tons each, weight of engine and tender 227 tons; gross weight train, including engine, 2927 tons; train resistance U. of I. Bulletin 43, page 35. (Velocity head increased by 4.83% to allow for rotation of wheels, see Raymond's Railroad Engineering.)

1	2	3	4	5	6	7	8	9	10	11	12	
Velocity	C. T. P.	Engine Resistance	D. B. Pull (P)	Train Resist. (R)	P—R	P—R Per Ton	Equiv. Grade %	Veloc. Head	Diff. in Vel. Head	Dist. to accelerate in stations	Total Dist. in Stations	Remarks
Start	543	28	515	181	324	11.40	......	0.00	......	......	......	Train Resist. (R) at starting from ordinary short stops at stations taken as 3 lbs. per ton more than that at 5 mi. per hour. Ave. 2 successive values in column (7) and divide by 20 to get value in column (8). Col. (10)÷(8)=(11). At top of grade with journals hot (R)=100 for 2 to 5 M. P. H., with P—R correspondingly reduced.
1	538	28	510	165	345	11.78	.580	0.03	.03	.05	.05	
2	532	28	504	149	355	12.13	.598	0.14	.11	.17	.22	
3	527	28	499	132	367	12.53	.616	0.31	.17	.28	.50	
4	522	28	494	116	378	12.90	.636	0.56	.25	.39	.89	
5	516	28	488	100	388	13.26	.654	0.87	.31	.47	1.36	
6	503	28	475	103	372	12.70	.649	1.26	.39	.60	1.96	
7	466	28	438	104	334	11.40	.602	1.72	.46	.76	2.72	
8	437	28	409	105	304	10.39	.545	2.24	.52	.95	3.67	
9	409	28	381	106	275	9.40	.495	2.84	.60	1.21	4.88	
10	385	28	357	107	250	8.55	.449	3.50	.66	1.47	6.35	
11	366	28	338	108	230	7.86	.410	4.24	.74	1.80	8.15	
12	348	28	320	109	211	7.22	.377	5.04	.80	2.12	10.27	
13	331	28	303	111	192	6.56	.345	5.91	.87	2.52	12.79	
14	316	28	288	113	175	5.98	.313	6.86	.95	3.03	15.82	
15	302	28	274	114	160	5.47	.286	7.87	1.01	3.53	19.35	
16	288	29	259	116	143	4.89	.259	8.96	1.09	4.20	23.55	
17	274	29	245	119	126	4.31	.230	10.11	1.15	5.00	28.55	
18	262	29	233	121	112	3.83	.202	11.34	1.23	6.09	34.61	
19	250	29	221	122	99	3.38	.180	12.64	1.30	7.22	41.83	
20	238	29	209	124	85	2.90	.157	14.00	1.36	8.67	50.50	
21	227	29	198	128	70	2.39	.132	15.44	1.44	10.90	61.40	
22	216	29	187	130	57	1.95	.108	16.94	1.50	13.90	75.30	
23	206	29	177	132	45	1.54	.087	18.52	1.58	18.20	93.50	
24	197	29	168	133	35	1.19	.068	20.16	1.64	24.10	117.60	
25	188	29	159	135	24	0.82	.050	21.88	1.72	34.40	152.00	
26	180	30	150	138	12	0.41	.031	23.66	1.78	57.40	209.40	
27	172	30	142	140	2	0.07	.012	25.52	1.84	155.00	364.40	

TABLE 2.

Acceleration on a level grade. Weight of train, 54 cars, 50 tons each=2700 tons; engine and tender, 227 tons, total weight of train 2927 tons. Corrected for Superheater. Using A. R. E. Assn. Formulas, 11,600 BTU, 4,000 lbs. of coal fired per hour. Train resistance above 5 miles per hour taken from U. of I. Bulletin No. 43, page 35.

Columns (2) to (6) inclusive in units of 100 pounds.

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1	2	3	4	5	6	7	8	9	10	11	12	
Velocity	C. T. P.	Engine Resistance	D. B. Pull (P)	Train Resist. (R)	P—R	P—R Per Ton	Equiv. Grade %	Velocity Head	Diff. in Vel. Hd.	Dist. to Accelerate in stations	Total Dist. in Stations	Remarks
Start	543	28	515	181	334	11.40	......	0.00	......	......	......	Train Resistance (R) at starting from ordinary short stops at stations taken as 3 lbs. per ton more than that at 5 M. P. H.
1	537	28	509	165	344	11.76	.579	0.03	.03	.05	.05	Average 2 successive values in Col. (7) and divide by 20 to get value in Col. (8).
2	531	28	503	149	354	12.10	.596	0.14	.11	.18	.23	Col. (10) divided by (8) equals (11).
3	524	28	496	132	364	12.44	.614	0.31	.17	.28	.51	
4	518	28	490	116	374	12.78	.630	0.56	.25	.40	.91	
5	512	28	484	100	384	13.12	.648	0.87	.31	.48	1.39	
6	471	28	443	103	340	11.62	.618	1.26	.39	.63	2.02	
7	435	28	407	104	303	10.35	.549	1.72	.46	.84	2.86	
8	405	28	377	105	272	9.30	.491	2.24	.52	1.06	3.92	
9	378	28	350	106	244	8.34	.441	2.84	.60	1.36	5.28	
10	357	28	329	107	222	7.58	.398	3.50	.66	1.66	6.94	
11	338	28	310	108	202	6.90	.364	4.24	.74	2.03	8.97	
12	320	28	292	109	183	6.26	.329	5.04	.80	2.43	11.40	
13	303	28	275	111	164	5.61	.296	5.91	.87	2.94	14.34	
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16	257	29	228	116	112	3.83	.207	8.96	1.09	5.26	27.50	
17	244	29	215	119	96	3.28	.177	10.11	1.15	6.50	34.00	
18	231	29	202	121	81	2.76	.151	11.24	1.23	8.14	42.14	
19	219	29	190	122	68	2.32	.127	12.64	1.30	10.23	52.37	
20	207	29	178	124	54	1.84	.105	14.00	1.36	12.84	65.21	
21	196	29	167	128	39	1.33	.079	15.44	1.44	18.34	83.55	
22	185	29	156	130	26	.89	.050	16.94	1.50	30.00	113.55	
23	176	29	147	132	15	.51	.035	18.52	1.58	45.20	158.75	
24	168	29	139	133	6	.20	.020	20.16	1.64	82.00	240.75	
24.6	......	......	......	......	0	.00	.005	21.18	1.02	204.00	444.75	
25	160	29	131	135	4	-.14	-.0035	21.88	.70	......	......	
26	153	30	123	138	-15	-.51	-.016	23.66	1.78	......	......	
27	147	30	117	140	-23	-.79	-.032	25.52	1.86	......	......	
28	141	30	111	154	-43	-1.47	-.056	27.44	1.92	......	......	

TABLE 3.

Acceleration on a level grade. Using A. R. E. Assn. Formulas, 11,600 BTU, 5000 lbs. coal per hour, corrected for Superheater. Columns (2)-(8) in units of 100 lbs.; weight of train 2700 tons; 54 cars, 50 tons each, weight of engine and tender 227 tons; gross weight train, including engine, 2927 tons; train resistance U. of I. Bulletin 43, page 35. (Velocity head increased by 4.83% to allow for rotation of wheels, see Raymond's Railroad Engineering.)

1	2	3	4	5	6	7	8	9	10	11	12	
Velocity	C. T. P.	Engine Resistance	D. B. Pull (P)	Train Resist. (R)	P—R	P—R Per Ton	Equiv. Grade %	Veloc. Head	Diff. in Vel. Head	Dist. to accelerate in stations	Total Dist. in Stations	Remarks
Start	543	28	515	181	324	11.40	....	0.00	....	....	....	Train Resist. (R) at starting from ordinary short stops at stations taken as 3 lbs. per ton more than that at 5 mi. per hour.
1	538	28	510	165	345	11.78	.580	0.03	.03	.05	.05	
2	532	28	504	149	355	12.13	.598	0.14	.11	.17	.22	
3	527	28	499	132	367	12.55	.618	0.31	.17	.28	.50	
4	522	28	494	116	378	12.90	.636	0.56	.25	.39	.89	
5	516	28	488	100	388	13.26	.654	0.87	.31	.47	1.36	Ave. 2 successive values in column (7) and divide by 20 to get value in column (8)
6	503	28	475	103	372	12.70	.649	1.26	.39	.60	1.96	
7	466	28	438	104	334	11.40	.604	1.72	.46	.76	2.72	
8	437	28	409	105	304	10.39	.545	2.24	.52	.95	3.67	Col. (10)÷(8)=(11)
9	409	28	381	106	275	9.40	.495	2.84	.60	1.21	4.88	At top of grade with journals hot (R)=100 for 3 to 5 M. P. H., with P—R correspondingly reduced.
10	385	28	357	107	250	8.55	.449	3.50	.66	1.47	6.35	
11	356	28	328	108	220	7.86	.410	4.24	.74	1.80	8.15	
12	348	28	320	109	211	7.22	.377	5.04	.80	2.12	10.27	
13	331	28	303	111	192	6.56	.345	5.91	.87	2.52	12.79	
14	316	28	288	113	175	5.95	.313	6.86	.95	3.03	15.82	
15	302	28	274	114	160	5.47	.285	7.87	1.01	3.53	19.35	
16	288	29	259	116	143	4.89	.259	8.96	1.09	4.20	23.55	
17	274	29	245	119	126	4.31	.230	10.11	1.15	5.00	28.55	
18	262	29	233	121	112	3.88	.202	11.34	1.23	6.06	34.61	
19	250	29	221	122	99	3.38	.180	12.64	1.30	7.22	41.83	
20	238	29	209	124	85	2.90	.157	14.00	1.36	8.67	50.50	
21	227	29	198	128	70	2.39	.132	15.44	1.44	10.90	61.40	
22	216	29	187	130	57	1.95	.108	16.94	1.50	13.90	75.30	
23	206	29	177	132	45	1.54	.087	18.52	1.58	18.20	93.50	
24	197	29	168	133	35	1.19	.068	20.16	1.64	24.10	117.60	
25	188	29	159	135	24	0.82	.050	21.88	1.72	34.40	152.00	
26	180	30	150	138	12	0.41	.031	23.66	1.78	57.40	209.40	
27	172	30	112	140	2	0.07	.012	25.52	1.86	155.00	364.40	

TABLE 4.

Accelerations and Retardations—Engine No...... (Superheater.) Train Tons=2700. Engine Tons=227. Gross Train Tons=2927. Max. Consumption Coal=4000 lbs. per hour. B. T. U.=11,600. (Velocity Head increased by 4.63% to allow for rotation of wheels, see page 186, Raymonds' "R. R. Engineering").

Velocity Miles per hr.	Diff. in Vel.Hd.	Level		+0.1		+0.2		+0.3		+0.4		+0.5		+0.6		+0.7	
		Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.	Net Eq. Grade	Dist. to accel. Stas.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Start																	
1	.08	.579	.05	.479	.06	.379	.08	.279	.11	.179	.17	.079	.38				
2	.11	.596	.18	.496	.22	.396	.28	.296	.37	.196	.56	.096	1.15				
3	.17	.614	.28	.514	.33	.414	.41	.314	.54	.214	.79	.114	1.49	.082	2.07	.018	9.55
4	.25	.630	.40	.530	.47	.430	.58	.330	.76	.230	1.19	.130	1.92	.071	3.52	.029	8.00
5	.31	.648	.48	.548	.57	.448	.69	.348	.89	.248	1.25	.148	2.09	.061	5.08	.039	8.00
5.78	.29													.028	10.36		
6	.10	.618	.63	.518	.75	.418	.93	.318	1.22	.218	1.79	.118	3.30	.010	10.00	.082	4.70
7	.46	.549	.84	.449	1.02	.349	1.32	.249	1.85	.149	3.08	.049	9.40	.051	9.00	.151	3.30
7.33	.17											.0087	19.50				
8	.35	.401	1.06	.301	1.33	.291	1.78	.191	2.72	.091	5.71	.0175	20.00	.109	4.77	.209	2.49
9	.60	.441	1.36	.341	1.76	.241	2.48	.141	4.25	.041	14.60	.059	10.16	.159	3.77	.259	2.32
9.45	.28									.0085	33.00						
10	.33	.398	1.65	.298	2.21	.198	3.33	.098	6.73	.0105	36.20	.102	6.47	.202	3.27	.302	2.18
11	.74	.364	2.08	.264	2.80	.164	4.51	.064	11.54	.036	20.56	.136	5.43	.236	3.13	.336	2.20
12	.80	.329	2.43	.229	3.49	.129	6.30	.029	27.54	.071	11.27	.171	4.67	.271	2.95	.371	2.18
12.4	.24							.0026	53.30								
13	.53	.296	2.94	.196	4.43	.096	9.07	.0038	54.20	.104	8.36	.204	4.36	.304	2.86	.404	2.15
14	.86	.265	3.58	.165	5.75	.065	14.60	.035	27.10	.135	7.08	.235	4.04	.335	2.84	.435	2.18
15	1.01	.234	4.82	.134	7.53	.034	29.70	.066	15.30	.166	6.08	.266	3.80	.366	2.76	.466	2.17
15.73	0.73					.011	70.90										
16	0.31	.207	5.26	.107	10.19	.004	77.50	.093	11.70	.193	6.65	.293	3.73	.393	2.78	.493	2.21
17	1.15	.177	6.80	.077	14.95	.023	50.00	.123	9.35	.223	5.15	.323	3.56	.423	2.73	.523	2.20
18	1.28	.151	8.14	.051	24.10	.049	25.10	.149	8.25	.249	4.93	.349	3.52	.449	2.74	.549	2.26
19	1.30	.127	10.28	.027	48.30	.073	17.80	.173	7.52	.273	4.76	.373	3.49	.473	2.75	.573	2.27
19.67	0.90			.008	112.50												
20	0.48	.105	12.94	.004	115.00	.095	14.30	.195	5.98	.295	4.81	.395	3.44	.495	2.75	.595	2.29
21	1.44	.079	18.24	.021	68.50	.121	11.90	.221	6.53	.321	4.49	.421	3.42	.521	2.73	.621	2.33
22	1.50	.050	30.00	.050	30.00	.150	10.00	.250	6.00	.350	4.28	.450	3.33	.550	2.73	.650	2.31
23	1.56	.035	45.30	.065	24.30	.165	9.00	.265	5.96	.365	4.33	.465	3.47	.565	2.79	.665	2.40
24	1.64	.020	82.00	.080	20.50	.180	9.10	.280	5.87	.380	4.32	.480	3.42	.580	2.83	.680	2.41
24.6	1.06	.005	204.00														
25	.70	[illegible]	[illegible]	.098	17.50	.198	8.70	.298	5.77	.398	4.33	.498	3.44	.598	[illegible]	.698	3.46
26	1.73	.016	111.00	.116	15.30	.216	8.35	.316	5.68	.416	4.28	.516	3.45	.616	2.90	.716	2.49
27	1.82	.032	58.00	.132	14.10	.232	8.08	.332	5.61	.432	4.31	.532	3.50	.632	2.94	.732	2.54
28	1.90	.054	34.00	.154	12.30	.254	7.50	.354	5.30	.454	4.21	.554	3.48	.654	2.98	.754	2.54

Train resist. uniform for Columns 15-18 from 0 to 5 M. P. H. 10,000 lbs.

TABLE 4—Continued.

Descending Grades—Accelerations

Veloc. Miles per hr.	−0.1		−0.2		−0.3		−0.4		−0.5		−0.6		−0.7	
	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.	Net Eq. Grade	Dist. to Accel. Stas.
	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Start														
1	.679	.04	.779	.04	.879	.03	.979	.03	1.079	.03	1.179	.03	1.279	.02
2	.696	.16	.796	.14	.896	.12	.996	.11	1.096	.10	1.196	.09	1.296	.08
3	.714	.24	.814	.21	.914	.19	1.014	.17	1.114	.15	1.214	.14	1.314	.13
4	.730	.34	.830	.30	.930	.27	1.030	.24	1.130	.22	1.230	.20	1.330	.19
5	.748	.41	.848	.37	.948	.33	1.048	.30	1.148	.27	1.248	.26	1.348	.23
6	.718	.54	.818	.48	.918	.42	1.018	.38	1.118	.35	1.218	.32	1.318	.30
7	.649	.71	.749	.61	.849	.54	.949	.49	1.049	.44	1.149	.40	1.249	.37
8	.591	.88	.691	.75	.791	.66	.891	.58	.991	.52	1.091	.48	1.191	.44
9	.541	1.11	.641	.94	.741	.81	.841	.71	.941	.64	1.041	.58	1.141	.53
10	.498	1.33	.598	1.10	.698	.95	.798	.83	.898	.74	.998	.66	1.098	.60
11	.464	1.59	.564	1.31	.664	1.11	.764	.97	.864	.86	.964	.77	1.064	.70
12	.429	1.86	.529	1.51	.629	1.27	.729	1.10	.829	.97	.929	.86	1.029	.78
13	.396	2.19	.496	1.75	.596	1.46	.696	1.25	.796	1.09	.896	.97	.996	.87
14	.365	2.60	.465	2.04	.565	1.68	.665	1.43	.765	1.24	.865	1.10	.965	.98
15	.334	3.03	.434	2.33	.534	1.89	.634	1.59	.734	1.38	.834	1.21	.934	1.08
16	.307	3.56	.407	2.68	.507	2.17	.607	1.80	.707	1.54	.807	1.35	.907	1.20
17	.277	4.16	.377	3.05	.477	2.41	.577	1.99	.677	1.70	.777	1.48	.877	1.31
18	.251	4.90	.351	3.51	.451	2.73	.551	2.24	.651	1.89	.751	1.64	.851	1.45
19	.227	5.72	.327	3.98	.427	3.04	.527	2.47	.627	2.08	.727	1.79	.827	1.57
20	.205	6.63	.305	4.47	.405	3.36	.505	2.69	.605	2.25	.705	1.93	.805	1.69
21	.179	8.05	.279	5.16	.379	3.80	.479	3.00	.579	2.49	.679	2.12	.779	1.85
22	.159	10.00	.259	6.00	.350	4.29	.450	3.34	.550	2.73	.650	2.31	.750	2.00
23	.135	11.79	.235	6.73	.335	4.72	.435	3.65	.535	2.96	.635	2.49	.735	2.15
24	.120	13.67	.220	7.45	.320	5.13	.420	3.91	.520	3.16	.620	2.64	.720	2.29
25	.102	16.80	.202	8.52	.302	5.69	.402	4.28	.502	3.43	.602	2.86	.702	2.45
26	.084	21.20	.184	9.68	.284	6.27	.384	4.63	.484	3.68	.584	3.05	.684	2.60
27	.068	27.30	.168	11.05	.268	6.94	.368	5.08	.468	3.98	.568	3.28	.668	2.79
28	.044	43.60	.144	13.30	.244	7.90	.344	5.53	.444	4.32	.544	3.53	.644	2.98

TABLE 5—2700 TON TRAIN, DRIFTING

Accelerations and Retardations, Locomotive No...... For simplicity the resistances in this table are taken as uniform from 5 to 30 miles. (A. R. E. Assn. Formula). Engine resistance=2900 lbs.; train resistance=2700×4.64=12,500. Total resistance=15,400 lbs.=5.26 lbs. per ton of gross weight of train (2,927 tons). Limiting Grade of Acceleration=—5.26÷20=—0.263.

Diff. in Velocity Head	Veloc. Miles per hr.	Drifting and Accelerating					Drifting and Retarding										Diff. in Vel. Head
		—0.7	—0.6	—0.5	—0.4	—0.3	—0.2	—0.1	0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	
.39	6	.89	1.16	1.64	2.84	10.50	6.20	2.35	1.50	1.05	.85	.69	.59	.51	.45	.40	.39
.46	7	1.05	1.37	1.94	3.36	12.40	7.30	2.80	1.75	1.25	1.00	.82	.69	.60	.53	.48	.46
.52	8	1.20	1.54	2.19	3.80	14.00	8.30	3.20	2.00	1.45	1.10	.93	.78	.68	.60	.54	.52
.60	9	1.40	1.78	2.53	4.38	16.20	9.50	3.70	2.30	1.65	1.30	1.05	.90	.79	.70	.62	.60
.66	10	1.50	1.96	2.78	4.82	17.80	10.50	4.05	2.50	1.80	1.40	1.20	1.00	.86	.77	.68	.66
.74	11	1.70	2.20	3.12	5.40	20.00	11.70	4.55	2.80	2.05	1.60	1.30	1.10	.97	.86	.77	.74
.80	12	1.85	2.38	3.37	5.84	21.60	12.70	4.90	3.05	2.20	1.75	1.40	1.20	1.05	.93	.83	.80
.87	13	2.00	2.58	3.67	6.35	23.50	13.80	5.35	3.30	2.40	1.90	1.55	1.30	1.15	1.00	.90	.87
.95	14	2.20	2.32	4.01	6.93	25.70	15.10	5.80	3.60	2.60	2.05	1.70	1.40	1.25	1.10	.99	.95
1.01	15	2.30	3.00	4.27	7.38	27.30	16.00	6.30	3.85	2.80	2.20	1.80	1.55	1.35	1.15	1.05	1.01
1.09	16	2.50	3.24	4.60	7.95	29.70	17.30	6.70	4.15	3.00	2.35	1.95	1.65	1.45	1.25	1.15	1.09
1.15	17	2.65	3.42	4.86	8.40	31.10	18.30	7.05	4.35	3.15	2.50	2.05	1.75	1.50	1.35	1.20	1.15
1.23	18	2.80	3.65	5.19	8.98	33.20	19.50	7.55	4.65	3.40	2.65	2.20	1.85	1.60	1.45	1.30	1.23
1.30	19	3.00	3.86	5.49	9.50	35.10	20.60	8.00	4.95	3.60	2.80	2.30	1.95	1.70	1.50	1.35	1.30
1.36	20	3.10	4.04	5.74	9.90	36.80	21.80	8.35	5.15	3.75	2.95	2.40	2.05	1.80	1.60	1.40	1.36
1.44	21	3.30	4.28	6.09	10.50	39.00	22.80	8.85	5.45	4.00	3.10	2.55	2.15	1.90	1.65	1.50	1.44
1.50	22	3.45	4.46	6.33	11.00	40.50	23.80	9.20	5.70	4.15	3.25	2.65	2.25	1.95	1.75	1.55	1.50
1.58	23	3.60	4.69	6.67	11.50	42.70	25.10	9.70	6.00	4.35	3.40	2.80	2.40	2.05	1.85	1.65	1.58
1.64	24	3.75	4.87	6.93	12.00	44.30	26.00	10.10	6.25	4.50	3.55	2.90	2.50	2.15	1.90	1.70	1.64
1.72	25	3.95	5.11	7.26	12.60	46.50	27.30	10.55	6.55	4.75	3.70	3.05	2.60	2.25	2.00	1.80	1.72
1.78	26	4.10	5.29	7.52	13.00	48.10	28.30	10.90	6.75	4.90	3.85	3.15	2.70	2.35	2.05	1.85	1.78
1.86	27	4.25	5.53	7.85	13.60	50.30	29.60	11.40	7.05	5.10	4.00	3.30	2.80	2.45	2.15	1.95	1.86
1.92	28	4.40	5.70	8.10	14.00	51.90	30.50	11.80	7.30	5.30	4.15	3.40	2.90	2.50	2.25	2.00	1.92
2.00	29	4.60	5.94	8.44	14.60	54.00	31.71	12.30	7.60	5.50	4.30	3.55	3.00	2.60	2.30	2.10	2.00
2.06	30	4.70	6.12	8.70	15.00	55.60	32.70	13.00	7.80	5.70	4.45	3.65	3.10	2.70	2.40	2.15	2.06

Accel. figure opposite 6 M.P.H.=dist. travelled to accelerate from 5 to 6 M.P.H., etc.
(Retardation figure opposite 6 miles means distance travelled to reduce speed from 6 to 5 miles per hour, etc.)

TABLE 6—4000 TON TRAIN, DRIFTING

Accelerations and Retardations. Locomotive No.... . For simplicity the resistances in this table are taken as uniform from 5 to 25 miles per hour. (A. R. E. Assn. Formula.) Engine resistance=2900 lbs., train resistance=4000 x 4.64=18,600. Total resistance=21,500 lbs.=5.09 lbs. per ton of gross weight of train (4227 tons). Limiting grade of acceleration=—5.09+20=—0.255.

Veloc. Miles per hr.	Diff. in Vel. Head	Locomotive Drifting and Accelerating										Locomotive Drifting and Retarding					
		—0.7		—0.6		—0.5		—0.4		—0.3		—0.2		—0.1		0.0	
		Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.
5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
6	.39	.90	.90	1.15	1.15	1.60	1.60	2.70	2.70	8.65	8.65	7.10	381.80	2.40	135.35	1.55	82.35
7	.46	1.05	1.95	1.35	2.50	1.90	3.50	3.15	5.85	10.20	18.85	8.35	374.70	2.95	132.95	1.80	80.80
8	.52	1.15	3.10	1.50	4.00	2.10	5.60	3.60	9.45	11.35	30.20	9.45	366.35	3.35	130.00	2.05	79.00
9	.60	1.35	4.45	1.75	5.75	2.45	8.05	4.15	13.60	13.30	43.50	10.90	356.90	3.85	126.65	2.35	76.95
10	.66	1.50	5.95	1.90	7.65	2.70	10.75	4.55	18.15	14.70	58.20	12.00	346.00	4.25	122.80	2.55	74.60
11	.74	1.65	7.60	2.15	9.80	3.00	13.75	5.10	23.25	16.40	74.60	13.45	334.00	4.75	118.55	2.90	72.05
12	.80	1.80	9.40	2.30	12.10	3.25	17.00	5.50	28.75	17.80	92.40	14.55	320.55	5.15	113.80	3.15	69.15
13	.87	1.95	11.35	2.50	14.60	3.55	20.55	6.00	34.75	19.30	111.70	15.80	306.00	5.60	108.65	3.40	66.00
14	.95	2.15	13.50	2.75	17.35	3.90	24.45	6.55	41.30	21.10	132.80	17.30	290.20	6.10	103.05	3.70	62.60
15	1.01	2.25	15.75	2.95	20.30	4.10	28.55	6.95	48.25	22.40	155.20	18.40	272.90	6.50	96.95	3.95	58.90
16	1.09	2.45	18.20	3.15	23.45	4.45	33.00	7.50	55.75	24.20	179.40	19.80	254.50	7.05	90.45	4.25	54.95
17	1.15	2.60	20.80	3.35	26.80	4.70	37.70	7.95	63.70	25.60	205.00	20.50	234.70	7.40	83.40	4.50	50.70
18	1.23	2.75	23.55	3.55	30.35	5.00	42.70	8.50	72.20	27.50	232.50	22.40	214.20	7.90	76.00	4.80	46.20
19	1.30	2.90	26.45	3.75	34.10	5.30	48.00	8.95	81.15	28.90	261.40	23.60	191.80	8.40	68.10	5.10	41.40
20	1.36	3.05	29.50	3.95	38.05	5.55	53.55	9.40	90.55	30.20	291.60	24.80	168.20	8.80	59.70	5.35	36.30
21	1.44	3.25	32.75	4.20	42.25	5.85	59.40	9.95	100.50	32.00	323.60	26.20	143.40	9.30	50.90	5.65	30.95
22	1.50	3.40	36.15	4.35	46.60	6.15	65.55	10.35	110.85	33.30	356.90	27.30	117.20	9.70	41.60	5.90	25.30
23	1.58	3.55	39.70	4.60	51.20	6.45	72.00	10.90	121.75	35.10	392.00	28.80	89.90	10.20	31.90	6.20	19.40
24	1.64	3.70	43.40	4.75	55.95	6.70	78.70	11.30	133.05	36.40	428.40	29.80	61.10	10.60	21.70	6.45	13.20
25	1.72	3.85	47.25	5.00	60.95	7.00	85.70	11.90	144.95	38.20	466.60	31.30	31.30	11.10	11.10	6.75	6.75

TABLE 6—4000 TON TRAIN—Continued

Veloc. Miles per hr.	Diff. in Vel. Head	LOCOMOTIVE DRIFTING AND RETARDING.													
		+0.1		+0.2		+0.3		+0.4		+0.5		+0.6		+0.7	
		Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.	Dist.	Total Dist.
5															
6	.39	1.10	59.30	.85	46.20	0.70	37.85	.60	32.10	.50	27.85	.45	24.55	.40	22.05
7	.46	1.30	58.20	1.00	45.35	0.85	37.15	.70	31.50	.60	27.35	.55	24.10	.50	21.65
8	.52	1.45	56.90	1.15	44.35	0.95	36.30	.80	30.80	.70	26.75	.60	23.55	.55	21.15
9	.60	1.70	55.45	1.30	43.20	1.10	35.35	.90	30.00	.80	26.05	.70	22.95	.65	20.60
10	.66	1.85	53.75	1.45	41.90	1.20	34.25	1.00	29.10	.90	25.25	.75	22.25	.70	19.95
11	.74	2.10	51.90	1.65	40.45	1.35	33.05	1.15	28.10	1.00	24.35	.85	21.50	.80	19.25
12	.80	2.25	49.80	1.75	38.80	1.45	31.70	1.20	26.95	1.05	23.35	.95	20.65	.85	18.45
13	.87	2.45	47.55	1.90	37.05	1.55	30.25	1.35	25.75	1.15	22.30	1.00	19.70	.90	17.60
14	.95	2.70	45.10	2.10	35.15	1.70	28.70	1.45	24.40	1.25	21.15	1.10	18.70	1.00	16.70
15	1.01	2.85	42.40	2.20	33.05	1.80	27.00	1.55	22.95	1.35	19.90	1.20	17.60	1.05	15.70
16	1.09	3.10	39.55	2.40	30.85	1.95	25.20	1.65	21.40	1.45	18.55	1.30	16.40	1.15	14.65
17	1.15	3.25	36.45	2.55	28.45	2.05	23.25	1.75	19.75	1.50	17.10	1.35	15.10	1.20	13.50
18	1.23	3.45	33.20	2.70	25.90	2.20	21.20	1.90	18.00	1.60	15.60	1.45	13.75	1.30	12.30
19	1.30	3.65	29.75	2.85	23.20	2.35	19.00	2.00	16.10	1.70	14.00	1.50	12.30	1.35	11.00
20	1.36	3.85	26.10	3.00	20.35	2.45	16.65	2.10	14.10	1.80	12.30	1.60	10.80	1.45	9.65
21	1.44	4.05	22.25	3.15	17.35	2.60	14.20	2.20	12.00	1.90	10.50	1.70	9.20	1.50	8.20
22	1.50	4.25	18.20	3.30	14.20	2.70	11.60	2.30	9.80	2.00	8.60	1.75	7.50	1.55	6.70
23	1.58	4.45	13.95	3.50	10.90	2.85	8.90	2.40	7.50	2.10	6.60	1.85	5.75	1.65	5.15
24	1.64	4.65	9.50	3.60	7.40	2.95	6.05	2.50	5.10	2.20	4.50	1.90	3.90	1.70	3.50
25	1.72	4.85	4.85	3.80	3.80	3.10	3.10	2.60	2.60	2.30	2.30	2.00	2.00	1.80	1.80

TABLE 8—TIME BETWEEN STATIONS

2700 Ton Train

STATION		Dist. in Miles	TIME IN HOURS			Miles per Hour
FROM	TO		Working	Drifting	Total	
South Yard....	Stop No. 1.......	21.37	1.19	0.26	1.45	14.7
Stop No. 1.....	" " 2.......	29.82	1.14	0.56	1.70	17.5
" " 2.....	" " 3.......	10.46	0.53	0.08	0.61	17.2
" " 3.....	" " 4.......	21.12	1.03	0.52	1.55	13.6
" " 4.....	" " 5.......	13.41	0.46	0.26	0.72	18.6
" " 5.....	North End Div..	28.08	1.29	0.39	1.68	16.7
South Yard...	North End. Div.	124.26	5.64	2.07	7.71	16.1

4000 Ton Train

STATION		Dist. in Miles	TIME IN HOURS			Miles per Hour
FROM	TO		Working	Drifting	Total	
South Yard...	Stop No. 1.......	21.37	1.69	0.18	1.87	11.4
Stop No. 1....	" " 2.......	29.73	1.54	0.45	1.99	14.9
" " 2....	" " 3.......	10.55	0.81	....	0.81	13.0
" " 3....	" " 4.......	15.68	1.24	0.20	1.44	10.9
" " 4....	" " 5.......	18.81	0.78	0.44	1.22	15.4
" " 5....	North End Div..	28.12	1.82	0.21	2.03	13.8
South Yard...	North End Div..	124.26	7.88	1.48	9.36	13.3

(9.36 hours÷7.71=1.21, or an increase of 21% in the running time between stations for the 4,000 ton train over the 2,700 ton train.)

FUEL

(See "Locomotive Fuel Consumption and the Speed Diagram," by A. K. Shurtleff, Vol. 14, Bull. No. 148, A. R. E. Assn.)

2700 Ton Train

5.22 hours working @ 4,000 lbs. 20,880
0.42 " " " 5,000 " 2,100
2.07 " drifting " 924 " 1,910
3.75 " standing " 509 " 1,910
26,800

11.46 " including Stops .... 13.40 Tons Coal
Through the South Yard (¾ hour)
Firing up, 4.07 @ 512 2,080 lbs.
Working(⅛)¾ hr. " 1,333 1,000 "
3,080 " .... 1.54 " "

Total over Division
129.75 miles, 12 hrs., 13 min .... 14.94 " "

4000 Ton Train

7.88 hours working @ 4,000 lbs. 31,520
1.48 " drifting " 924 " 1,370
3.75 " standing " 509 " 1,910
34,800

13.11 " including Stops .... 17.4 Tons Coal
Through the South Yard (1 hour)
Firing up, 4.07 @ 512 2,080 lbs..
Working(⅛)1 hr. " 1,333 1,330 "
3,410 " .... 1.7 " "

Total over Division
129.75 miles, 14 hrs., 7 min .... 19.1 " "

TABLE 9—SHOWING TIME OF TRAINS OF VARIOUS LOADING OVER DIVISION

Engine Working over 108 miles (North of South Yard), and Drifting over 21.26 miles.

Total Fuel Consumption, Tons	Cars & Loads Tons	South Yard to North End of Division: Equivalent Grade	Speed on Equivalent Grade	Hours Running Time: Working	Hours Running Time: Drifting	Hours Running Time: Total	On +0.3% Grade: D. B. Pull	On +0.3% Grade: Speed	Corresponding Time through South Yard	Total running Time over Division	Total Time over Division including stops	Tons over Division per engine hour	Thousand Ton Miles per engine hour	Pounds Coal per ton of cars and loads
14.94	2700	0.181	16.4	5.64	2.07	7.71	27,200	12.40	0.75	8.46	12.21	221	28.7	11.07
16.41	3150	0.164	15.0	6.50	1.83	8.33	31,500	10.00	0.84	9.17	12.92	244	31.7	10.42
17.61	3550	0.147	14.0	7.17	1.66	8.83	35,100	8.46	0.92	9.75	13 50	263	34.2	9.92
18.42	3780	0.138	13.5	7.58	1.56	9.09	37,200	7.70	0.96	10.05	13.80	274	35.6	9.75
19.11	4000	0.13	13.07	7.88	1.48	9.36	39,200	7.04	1.00	10.36	14.11	283	36.8	9.55
	4100													
	4200													
20.55	4300	0.13	12.00	8.58	1.48	10.06	42,100	6.22	1.07	11 13	14.88	289	37.5	9.56
	4400													
	4500													
	4600													
22.17	4610	0.13	11.00	9.36	1.48	10.84	44,900	5.52	1.16	12.00	15.75	291	37.8	9.60
	4700													
	4800													
	4900													
24.12	4980	0.13	10 00	10.30	1.48	11.78	47,700	3 82	1.26	13.04	16.79	294	38.2	9.78
	5000													
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

THE UNIFICATION OF THE FREIGHT TERMINALS OF A LARGE CITY.

GEO. H. KIMBALL.

In its seventh annual report (Bulletin No. 71) the Committee on Yards and Terminals quoted the following extracts from an article in the "Iron Age" of September 7, 1905:

"The transportation facilities of the country broke down under the weight of prosperity in 1902 and 1903, not so much because the supply of locomotives and cars was insufficient, though that was a factor, as from the utter inadequacy of terminal facilities. . . . .

"In every important railroad city of the country the question of terminals has been a threatening one for years. Naturally it is one of infinite difficulty, the acquisition of needed property being often a matter of years. Moreover, expenditures for terminals have so much of the element of providing for the distant future that directorates find it expedient to postpone them and put money into equipment that can begin paying its way the day it is delivered from the maker. Frequently the heavy outlay involved in terminal improvements and the obstacles to financing them in times of slack business have put them off indefinitely. Yet, it has been demonstrated time and again that the returns terminal expenditures would have yielded in the next burst of prosperity following their completion would have paid interest on the money for years."

The Committee made no particular comment on this extract from the "Iron Age," and evidently adopted and submitted it as their own view of the situation as it existed at the time. The report referred to was dated January, 1906, and applied particularly to large city freight terminals. That the general situation relative to the growth of traffic and condition of terminals remains unchanged to-day rests on very eminent authority.

In a recent address, by Mr. James J. Hill, he stated in part as follows:

*"Every interest and every community should understand that the main need to-day of transportation and of the many activities connected with and dependent upon it is an increase of terminal facilities. It is no exaggeration to say that the commerce of the country, its manufacturing and agricultural industry, its prosperity as a whole, and the welfare of every man in it who engages in any gainful occupation, can escape threatened disaster only by such additions to and enlargements of existing terminals at our great central markets and our principal points of export as will relieve the congestion that now paralyzes traffic when any unusual demand is made upon them.

"Our natural material growth will make this their chronic condition in the near future unless quick action is taken.

"If you increase the size of a bottle without enlarging the neck. more time and work are required to fill and empty it. That is what has happened to the transportation business."

The freight traffic of the country increases by leaps and bounds—one hundred per cent. in the past ten years—and we can confidently

*Extract from an address made by Mr. Hill at the Annual Dinner of the Railway Business Men's Association in New York, December 19, 1912.

anticipate its average increase in the period of years at a constantly accelerating rate.

The era of railroad reconstruction and improvement has prevailed for many years, but large city freight terminals in spite of their paramount importance, and the fact that they are a limiting factor in the transportation problem, have lagged far behind and have received only such attention as circumstances compelled, to keep them limping along.

Large city freight terminals form a vital part of every railroad system—the "solar plexus," so to speak—upon which vitality or paralysis absolutely depend. Without such terminals, properly arranged and smoothly operated, prompt and efficient transportation movements become impossible.

The difficulty in general, as the writer conceives of it, seems to be not so much a matter of the number and capacity of yards and tracks, as of their location and lack of systematic arrangement, of a rational design in the adaptation of means to ends, coupled with an efficient operating system, and certain reforms in business details that have a retarding influence on the movements of freight traffic.

The urgent need of radical measures in dealing with the problem of large city freight terminals seems to justify the thought that the investigation made at Buffalo in which the writer took part, and the conclusions reached in the course of that experience, may be of interest and contribute something to the fund of information on the general subject of yards and terminals.

The Buffalo Freight Terminals Committee was organized for the purpose of making a comprehensive study of terminal conditions in and about the city of Buffalo, and was composed of the Superintendents, General Superintendents or Superintendents of Terminals of the trunk lines of railroad centering at that point.

Its object was to provide for systematic operation; increased capacity and efficiency, and the relief of periodic congestion. This work was continued for two years or more and closed with the Committee's final report in May, 1904. It involved so great an undertaking that the recommendations of the Committee were not carried out and while improvements have necessarily been made from time to time to keep pace with the growth of traffic, the same relative conditions prevail, and the lapse of time has served to emphasize the importance of the problem and of the conclusions reached in the effort made for its solution.

Every large city presents special problems concerning its freight terminals, which are determined in a general way by the routes of approach necessarily occupied by lines of railroad converging on a common point, due to topographical features, public improvements or other artificial conditions.

The city of Buffalo has its peculiarities in this respect, which present more than ordinary difficulties. Located at the outlet of Lake Erie and fronting on the lake and on the Niagara River, the lines of approach are confined to two general routes; one from the east and south confined

practically within an angle of ninety degrees (see map), and including the railroads within that angle and those approaching along the south shore of the lake, and one from the north including the Canadian lines of railroad that cross the frontier at Black Rock and Suspension Bridge.

On the Canadian side of the Niagara River, opposite Black Rock, the following named railroads converge to a common connection with the International Bridge:

Grand Tiunk Railway Syhtem;
Michigan Central Railroad;
Wabash Railroad;
Pere Marquette Railroad;
Toronto, Hamilton & Buffalo Railroad.

On the Black Rock side of the river the yards of the following named railroads lie practically parallel and just north of the connection with the International Bridge: D. L. & W., Grand Trunk, Erie, and New York Central.

There are seventeen steam railroads converging on Buffalo, the large majority of which reach the heart of the city by their own lines of rails and have their own terminals.

Large city terminals may be divided into three general classes, as follows:

(1) Seaboard and lake terminals, which are terminals proper, where all traffic is classified or its classification broken, for forwarding via the home line, or for distribution at the terminal, as follows:

(a) Interchange with connecting rail routes.

(b) Interchange (loading and unloading) for connecting water routes.

(c) To and from industries.

(d) To and from city freight houses and team tracks.

(2) Inland or all-rail terminals, which are terminals proper, comprising all of the features in class one, except interchange with water routes.

(3) Intermediate or division terminals, where the terminal work of a large city and connecting lines combines with the work of two or more operating divisions.

This classification might be further extended, but there are permanent characteristics to differentiate these three classes of terminals. In these cases, and in all modifications of them that may arise, the special difficulties of general location; the limitations due to public improvements, arbitrary land lines, character and volume of traffic, as well as commercial considerations that prevent the prompt handling of certain classes of business and so complicate yard work, make the arrangement and operation of large city terminals a problem of exceeding difficulty.

The railroad terminals of the city of Buffalo naturally fall under the first head in the above classification. The essential problem at that point has not yet been solved, and it is probable that on the whole Buffalo presents the most difficult situation of any great city between Chicago and the seaboard.

It is to be noted that the various lines of railroad in and about Buffalo connect and lie closely parallel at three widely separate points, forming an area roughly triangular. These points are Black Rock on the north, where the traffic via the north shore or Canadian lines crosses the frontier by the International Bridge; Blasdell on the south, where the south shore lines and lines from the south and east converge, and Lancaster on the east; the last named point being directly connected with Blasdell by the Terminal Railroad of Buffalo (New York Central Railroad System), and with Black Rock less directly by the belt lines of the New York Central Railroad, the Erie Railroad and the Delaware, Lackawanna & Western Railroad. These belt lines just referred to also serve as connections to and from the south, there being no connection for through freight movement from Black Rock south along or parallel to the water front.

Practically all of the Buffalo terminal facilities, including those serving the water routes, the local freight stations and the outer yards lie within the angle between the lines east and west, and north and south before referred to (southeast quadrant), the only exception being the yard at Black Rock and its connections where the business is largely direct interchange, handled by switching movements to and from the outer yards in the southeast quadrant just referred to, and via the International Bridge.

This brief survey of the Buffalo Terminal District, as it came to be known, presents the general features of the situation and brings us to a point where the general conclusions of the Committee may be presented and considered.

These conclusions embodied the following factors:

(1) The formation of a general switching association to be organized and equipped for carrying on all of the terminal work of the lines in interest.

(2) The combination, under the control of the proposed association, of all of the terminal property and equipment required, or in any way necessary, for carrying on its work.

(3) The terminal territory of all of the lines in interest within the Buffalo Terminal District to be made common territory; that is, open terminals with unrestricted interchange, and the same conditions to all concerned for similar service.

(4) Such arrangements of yards and connections to be made as would divert through traffic from the congested districts, and prevent reverse and duplicate switching and interchange movements.

(5) The proper location, design and construction of a general classification and clearing yard of ample capacity for the needs of the time and capable of natural expansion without rearrangement or reconstruction to provide for future growth of traffic.

(6) The construction of auxiliary yards at Blasdell and Black Rock to provide for the interchange traffic via the International Bridge at the

last named point, and for local freight for city delivery at both points, so as to avoid reverse movements.

In a word, these conclusions called for a unification of all railroad and water terminals; for a track system specifically designed to adapt means to ends to the fullest extent possible in the handling of freight traffic, and for an operating system capable of economy and dispatch.

It was confidently expected that such a system as was proposed would not only avoid congestion and provide for a more prompt movement than had ever been possible before, but that it would stimulate the growth of Buffalo as an industrial center, increase the local business, result in very great economy in terminal service and prevent the construction of additional belt lines by outside parties, and the assumption by existing railroads of the burdens an independent terminal involves.

In continuing the investigation of the subject in hand statistics were compiled showing the maximum movement of freight traffic in and through the Buffalo Terminal District. These statistics were subdivided and classified in considerable detail, according to the requirements of the case as shown by the blank form attached hereto.

At this point in the process of investigation the greatest problem of all involved in the general proposition, that of the location and conformation of the general classification and clearing yard, was taken in hand, and as the central or controlling factor in development was followed in detail to completion, and to this work the writer was specially assigned.

By a process of elimination a location was at length decided upon just east of Lancaster. At this point four of the most important trunk lines of railroad lie within very narrow limits, are practically parallel for a long distance, and then diverge eastward. This fact, together with that of direct connections, beginning just west of Lancaster, and extending to Suspension Bridge, Black Rock (International Bridge), Buffalo proper and Blasdell, show this location, on the east point of the triangular area comprising the Buffalo Terminal District, to be the logical location for the general classification and clearing yard, the auxiliary yards at Black Rock and Blasdell being located at the opposite angles of the triangular area referred to.

The details of various minor problems, with reference to changes in existing tracks and connections to permit direct movements in diverting trains outside of the congested district, were worked out in connection with the problem of locating the clearing yard.

Due regard was paid to the direction of the center line of the yard with reference to prevailing winds and the probable effect of extreme weather conditions.

The design of the classification and clearing yard was controlled by factors and conditions far greater in number and magnitude than in any work of the kind previously attempted, and so far as known, attempted up to the present time. All of the freight traffic passing the Buffalo gateway, excepting local freight from the west, was to be provided for, and

all of the work performed in receiving, classifying and delivering, city and industrial business, lake freight and interchange, including car repairs, and the care of the engines and light repairs to same. In brief all of the work of a freight terminal in any way involved in receiving, handling and forwarding the business, together with maintaining the efficiency of the equipment, facilities and appliances. What had so far been attempted by only a single railroad at its terminals, in the switching and classifying of its traffic, was to be done for ten or more important lines combined with a heavy lake traffic and the work of an extensive city and industrial district.

As there was no precedent to follow, the problem of design became one of making the best adaptation possible of known principles and appliances to larger needs.

A list of the requirements necessary for a yard of this character will be found in the appendix. This was largely an outgrowth of the investigation and was not prepared in advance as a guide.

The method was followed of designing the essential features of a track plan without regard to road lines, land lines, topography or any other possibly limiting object, and then adapting it to the location desired. This proved a very satisfactory way.

For obvious reasons it was necessary to carry on the work with secrecy. No surveys were permissible, and the information required of that kind was compiled as far as possible from existing maps and profiles, with such detached measurements and special observations as were possible under the circumstances, to check and unify the whole.

A classification and clearing yard is a composite affair and comprises an extensive group of closely connected and inter-related yards. The first division is determined by the opposing movements of the traffic, which, in this case, was substantially balanced so far as the general capacity of the yard was concerned, and requiring an eastbound yard and a westbound yard practically identical in arrangement, excepting that the eastbound yard had the added feature of stock yards and icing stations. Thus the general design became two parallel hump yards identical in plan, but reversed as to direction of movement of traffic. The humps were located as nearly opposite as possible to permit the ready transfer of engines and car riders from one yard to the other in order to equalize the number of engines and the force of men required under varying conditions of traffic.

From this point it will be convenient for the writer to follow for a time the wording of his report on this subject, which recites as follows:

"The classification and clearing yard, as a whole, will consist of an eastbound yard and a westbound yard substantially parallel to each other, and as, with the exception of the provision for stock yards and for refrigerator freight, the two yards will be essentially duplicates, the description that follows will be confined to the eastbound yard which includes the facilities for handling stock and refrigerator freight.

"This yard (eastbound) must have a capacity for handling 5,000 cars in each 24-hour period. It will consist of a receiving yard, a classification yard, a repair yard and a forwarding yard, all arranged in linear

order from west to east, so that a forward movement in the direction of the traffic is provided for with the possible exception of repaired cars. Stock yards and icing stations are provided for in connection with this yard, but are separately operated. Facilities for caring for and handling engines and cabooses, for fuel and water supply, car repairs and all of the numerous details that go to make up a complete terminal are of course included.

"To handle 5,000 cars per day will require the regular service of two engines working over the hump, and this suggests a track system divided longitudinally into two sections for convenience in working, but so connected that they are in effect one yard.

"This feature, the requirements of classification, and the fact that the eastbound lines in interest diverge at last to right and left (north and south) make it feasible and desirable to separate the eastbound lines into two groups and assign to them sections of the classification yard and forwarding yard to right and left of the center line.

"I have therefore carried out this idea of a longitudinal division for the entire length of the eastbound yard (westbound also), but the sections are so intimately connected that all of the cross movements that can possibly be required are provided for.

RECEIVING YARD, CAPACITY 2,750 CARS.

"The receiving yard is divided transversely by slip switches into two sections, a receiving section and a hump section and each consists of two parallel groups of tracks with twelve tracks in each group. The exterior tracks of each group are reserved for thoroughfare tracks and are not included in estimating capacity. It is assumed that a rough or partial classification can be provided for in the make up of incoming trains. This separation is feasible and is desirable, and can be made by trains or by groups of cars in trains. It is not unreasonable to expect that in view of the large amount of classification work to be performed by the clearing yard, the lines in interest can establish rules requiring inbound trains to be made up with solid groups of cars for lines connecting through the terminal.

"Engines will 'feed' cars from the receiving section to the hump section of the receiving yard as fast as tracks in the latter section are cleared by the hump engines, or all engines can be worked in a circuit, including the receiving section and the hump section.

CLASSIFICATION YARD, CAPACITY 2,200 CARS.

"Classification yards generally serve a double purpose; that is, both for classifying cars and making up trains on the same group of tracks. The large number of classifications to be made in this case make it imperative to provide a yard for classification purposes exclusively, so that cars can be grouped in cuts, on tracks provided for each road and its principal stations and junction points, these cuts to be run to the tracks in the forwarding yard in the order determined for made up trains. A separate group of classification tracks is provided for each hump engine with connections at both ends with the classification group opposite.

"There are 65 classification tracks in each group; that is, 130 classification tracks in the eastbound and a like number in the westbound yard. These groups are understood to be arbitrarily divided longitudinally by tracks reserved as thoroughfare tracks, into secondary groups, and one group is assumed to be assigned to each road for which trains are to be made up. The plan is perfectly flexible, as any track can be designated as a thoroughfare track for this purpose, and the number of tracks in each secondary group can thus be made to suit unequal or varying requirements.

TRACK SCALES.

"Track scales are located just over the hump at the head of the classification yard on independent tracks with grades adjusted to suit the service. There are two scales one for each section of the classification yard, referring, of course, to the main longitudinal divisions, with tracks and connections so arranged that either scale can be used to weigh cars for either or both divisions of the classification yard as required. These scales should be 75 feet in length with all modern attachments, the device for automatically recording the weight being particularly necessary.

"Repair Yards, Working Capacity............1,060 Cars
"Additional Holding Capacity................ 900 Cars

"Repair yards occupy the space between the classification yards and the forwarding yards. The grade falls slightly in the direction of the traffic, so that cars can be easily moved by hand or with a cable and stationary power. The yard is divided into sections as follows: A holding section, a working section and a section for repaired cars. In the working section tracks are spaced alternately 15 feet and 25 feet centers. The wide intervals are intended to include standard gage service tracks for handling wheels and repair materials. The length of track provided for cars under repair is 45 feet. In the working section of the repair yard groups of tracks are provided as follows:

"(1) First-class or time freight.
"(2) Second-class or slow freight.
"(3) Light repairs such as wheels, truck repairs and draft rigging.
"(4) Medium repairs such as ends, end sills, etc.
"(5) Heavy repairs.

"Transfer tracks and platforms are also provided for.

FORWARDING YARDS, CAPACITY 9,200 CARS.

"There are two forwarding yards side by side, each composed of two groups of twenty-five tracks each. The exterior tracks of each group are reserved for thoroughfare tracks and are not included in estimating capacity. These forwarding yards are to be further divided under working conditions into smaller groups of tracks by assignment to the different railroads, according to their requirements.

"The relatively large capacity of the forwarding yards is noticeable, but the only proper place for the prolonged holding of cars is in the forwarding yard in made-up trains ready for road movement. To insure smoothness, certainty and consequently capacity in the working of a hump yard the receiving end should be kept practically clear, that is with the traffic moving freely through it, particularly so in cold weather, and it should never be allowed to fill up to check the movement except in some serious emergency.

CABOOSE YARDS, CAPACITY 100 CABOOSE CARS.

"The location of the caboose yards is shown between the extreme ends of the forwarding yards, the intention being to handle the cabooses with electric motor cars. The locations shown provide for putting cabooses on made-up trains in the forwarding yard or as they pull out of the forwarding yard, and it has the advantage of separating the movements of cabooses from all other movements to the greatest extent possible.

PROFILE.

tions. A uniform grade for the classification yard follows: It should be from 0.6 per cent. to 0.7 per cent. in order to start the cars by gravity to make the run to the forwarding yard. The grade beyond the classification yard can then be reduced to 0.5 per cent., 0.4 per cent. and 0.3 per cent.

"On account of the extreme length, unavoidable for trains of 100 cars, as specified, it will not be possible to work the eastbound forwarding yard for its full length by gravity, and it will be necessary for engines to bunch the cars at the lower end. (The westbound yard can be worked by gravity for its full length.)

TROLLEY TRACKS, ETC.

"Provision has been made for a double line of trolley tracks in the central space between the longitudinal sections of both eastbound and westbound yards. These tracks will extend from a point near the hump to the extreme ends of the forwarding yards, and will be constructed in subways where cross connections are made between adjacent sections of the yard, passing the repair yard and at the hump. These facilities provide for prompt handling of car riders on the return trip to the hump.

ENGINE LOOPS, ETC.

"Provision is made for the continuous forward movement of road engines from the time they are cut off of trains in the receiving yard, until they reach the coal dock, ash pit and engine yard, and thence to outbound trains the engines being turned in the process without the use of turntables. In the course of this circuit they pass between and under the humps. There is no interference with other traffic, nor is the engine movement interfered with. While the distance to be covered by engines in making this movement may appear to be considerable, the time element is the real factor, and on this basis the design proposed has every advantage.

"A sufficient number of tracks is provided in the engine yard so that the engines of each road can be assigned to separate tracks. This detail is necessary to facilitate the outward movement of various classes of engine service, as well as for the different roads. After entering the engine yard engines will pass through a house and over pits, arranged for thawing out when necessary.

"Fuel storage is provided for adjacent to the coal dock, as well as for an additional supply on cars. These facilities, as shown, have a capacity sufficient for the roads in interest and the plan is capable of natural expansion to include other lines as well.

STOCK YARDS AND ICING STATIONS.

"Stock yards and icing stations are arranged in two groups in order to avoid reverse movements and grade crossings; this also favors the division of the traffic by roads as it diverges east from the clearing yard. One lead track for this section of the yard can include a low hump for sorting purposes if necessary. The capacity shown is much in excess of the present maximum requirements.

POWER HOUSE.

"A centrally located power house is required as a source of compressed air and electric power, light, heat and water supply. It must be of relatively large capacity, provided for ready expansion, and contain all of the modern appliances that contribute to economy and efficiency.

INTERLOCKING, LIGHTING, ETC.

"The interlocking of this yard will naturally be divided into sections determined by the divisions of the yard and the service requirements. For example, the two longitudinal divisions of the classification yard will be separately interlocked, and will be controlled by independent signalmen at the hump, and will be interlocked as between the two main longitudinal divisions at points of connection so that the co-operation of the signalmen will be required to make cross movements.

"Not all switches or groups of switches need to be interlocked, but all switches should be moved by electric or pneumatic power from central stations, and all switches should be electrically lighted.

"Arc lights are to be provided for all switch leads, thoroughfare tracts, engine tracks, ash pits, coal docks, etc. Compressed air supply and testing plants are required for the repair yards and for testing made-up trains, also for testing and power purposes in the repair shops. Pneumatic tubes are included for the transmission of way bills and for similar purposes.

TELEPHONE SYSTEM, WATER SUPPLY, FIRE PROTECTION, DRAINAGE, ETC.

"A very complete telephone system is, of course, essential and has been included in the estimate of cost.

"Particular attention has been given to the question of drainage, both natural and artificial, also provision has been made for an ample supply of good water, with a standpipe to provide pressure for distribution and a storage reservoir to tide over any emergency. The mains of the Depew & Lake Erie Water Co. can be readily extended to the location chosen for the storage reservoir.

"Ample provision for fire protection has been made at all critical points, and special provision for apparatus on cars and for the general equipment of switch engines."

CABLE HAULAGE PROPOSED IN PLACE OF SWITCH ENGINES WITH THE OBJECT OF INCREASING CAPACITY.

Throughout the investigation indicated by the above, the question of the possibility of increasing the capacity of hump yards was kept constantly in view.

The hump is the limiting point, and its efficiency, as determined by the design and the operation at that point, determine the capacity of the yard. Everything depends upon this factor in the problem and it is, perhaps, ordinarily the weakest link in the chain.

To insure the continuous service of two switch engines at one hump, four tracks were provided, designed to be operated in pairs with the object of operating the opposite tracks of each pair alternately, thus keeping up a steady movement of two lines of cars over the hump, by bringing in a second line of cars on the opposite track of each pair, while the first two lines of cars are being classified: that is to say, that it would take four switch engines to keep up a continuous movement on two tracks. The four-track arrangement also minimizes the effect of derailments, as it is very improbable that more than one track would be thus obstructed at any one time. Beyond this, however, extreme weather conditions sometimes defeat all calculations, and in a yard of this character it was

desirable to be free from the effect of high winds and sleet, if possible, as well as to increase the normal capacity at the hump.

The writer at length hit upon the plan of a modified cable haulage system. It was manifest that with the weight assumed to be handled, 50 cars, estimated at 2,250 tons, applied at one point on the cable, the "grip" system was useless, and it was found necessary to insert in the cable a heavy link of special design; as such a device could not be operated over the drums of the winding machinery provisions were made for reversing the movement of the cables, and here the four tracks over the hump fitted into the plan as well as before, as cars could be moved on one track while the cable was being reversed on the other.

Special cars were designed for picking up the cable by means of appliances operated by compressed air. These cars to be held by brakes on a short switch-back grade from which they ran out by gravity behind a cut of cars pushed up from the lower end of the receiving yard, and dropping back by gravity to the starting point. The *eastbound yard* on the plan accompanying this Bulletin shows the track arrangement as proposed for cable haulage.

The following extracts quoted from my supplementary report on this subject, made at the time, will perhaps present the matter with greater clearness:

"The second change proposed is a radical departure from the present method of working hump yards, and consists in the application of stationary power and cables for handling cars in the hump section of the receiving yard, and over the hump, in place of switch engines.

"There is nothing experimental in the proposed use of such appliances, and nothing new except the adaptation of standard machinery to a new purpose where the conditions are in no sense difficult. Even the weight to be handled does not exceed that formerly controlled on 'grip lines,' where the conditions of the service was very much more complicated.

"The present limit of capacity in yards of this character is the number of cars one or more engines will handle over a hump in a given time. Increase of track room, and other facilities cut no figure whatever, as the engine service at the hump exactly measures the volume of traffic that can be moved through such a yard. This application of stationary power will, in my judgment, practically double the capacity of the clearing yard, without any other change in the arrangement or increase in its facilities.

"I see no difficulty whatever in adapting such appliances to the requirements of the service, and that I have attempted to do in what follows. The plan proposed practically eliminates the effect of weather conditions on the ascending side of the hump, and the power is more reliable, economical and under better control.

"In applying this method, all of the tracks in the hump section of the receiving yard are omitted, except the four tracks passing over the hump, and these remain exactly as before.

"Without disclosing the real purpose in view, I submitted the problem to the Wellman-Seaver-Morgan Co. of Cleveland, Ohio, as follows:

"'Given four tracks on a 2 per cent. grade about 3,000 ft. in length, the track spaces 20 ft. and 15 ft. on centers, in the central and side intervals, respectively, to elevate loads of 2,250 tons, alternately on each track of a pair, at a normal speed of not less than five miles per hour. Each pair of tracks to be worked independently, and provision to be

made for reversing the motion of, and tension on the cables. The power to be sufficient to start the load (assumed to represent 50 average loaded freight cars) from a state of rest on the grade.

"It was further specified that the engines should be in pairs, both engines of a pair to be able to hoist together, alternating on either track of the pair of tracks they serve.

"That is to say, that there will be cables and winding machinery for four tracks, to work independently, and a pair of engines for each pair of tracks the combined power of one pair of engines being sufficient to operate one track, and so arranged that the power can be applied on either track of a pair at will.

"The machinery to be located in a concrete structure below grade at the crest of the hump. The tracks carried on concrete arches, the winding machinery being located in the spaces under the arches, and the engines located in the spaces between the arches, which spaces are covered over like a subway so as to exclude water and support derailed cars. A general plan was prepared to fulfill these conditions and show its relation to the general scheme, a copy of which is shown herewith on the plan of the classification and clearing yard.

"In stating the problem it was my purpose to fix, what seemed to me, limiting conditions so that any modification that might be made could only affect the problem favorably.

"A 2 per cent. grade is hardly necessary and I think that 1½ per cent. need not be exceeded in this particular case.

"The duplication of machinery, primarily necessary to give sufficient capacity within reasonable space prevents the possibility of serious interruption by breakdown, or when making renewals or repairs.

"The tonnage specified is probably in excess of what would have to be handled under everyday conditions. It should be noted that the element of wear that so rapidly destroys the cable on grip lines is entirely absent in this case.

"A positive cable connection is made by means of a car of special construction called a follower, that is switched by gravity in behind the cuts of cars to be handled. This car takes up the tension in the cable and transmits it as a thrust to the rear drawhead of the last car of the cut.

"Under this arrangement the constant movement over the hump of two lines of cars can be maintained at an average speed of not less than five miles per hour.

"The manufacturers of cable machinery to whom this problem was submitted—the best and most highly experienced in their line—expressed their entire willingness to undertake the contract and guarantee results. Plans were prepared and an estimate of cost submitted. General plans showing the arrangement of machinery and cables at the hump are shown on the clearing-yard plan submitted herewith."

WRITER'S COMMENTS UP TO DATE.

The investigation above referred to was concluded in May, 1904, and the subject has been presented as it was considered and developed at the time. As has been shown, the relative situation concerning congestion and delay at large city freight terminals remains substantially unchanged.

Experience and observation since that time have only served to strengthen my belief in the wisdom of the conclusions formulated by the Buffalo Freight Terminals Committee.

While it is true that hostility to the idea of open terminals is common, and the thought of placing all railroads and their patrons on an equal footing, so far as terminal service is concerned, with "reciprocal switching" applied to competitive as well as non-competitive business, finds little favor, yet in the main the conclusion is sound and merits serious consideration. In the older and more congested districts industrial development has already reached its limit, and without the opening of new districts that condition would soon prevail. Where industrial expansion seeks new territory on connecting lines and additional business is within reach, some substantial return as between railroads must be made if a share of new business is to be secured: furthermore, there are locations where industrial development has been dwarfed by a short-sighted policy in this respect, and the alternative has been, and may again be presented, of a choice between open terminals and the assumption of the burdens an independent terminal involves. Shippers have also learned to appreciate the value of a location where there is perfect freedom and flexibility pertaining to transportation.

The unification of terminals, however, *as to operation*, does not necessarily involve the idea of open terminal territory. Without it the unification of terminal operations would seem to be desirable on the score of efficiency, economy and dispatch. It is not even essential that a terminal association should be formed as a separate entity to take over and hold the terminal property necessary to be combined. An association for the operation of terminals as a unit may be confined to the *use* of the terminal facilities so combined. The title of ownership to lands, to tracks, equipment, etc., can remain in the parties in interest. The adjustment of accounts need not be a difficult matter and could be fairly based:

(1) On the interest on the value of the property contributed by each railroad, equalizing the inevitable inequalities; and

(2) Pro-rating the cost of maintenance and service.

An objection has been offered to a clearing yard of the character described simply on the score of its size, with the thought that it might be cumbersome and difficult of operation, but when we consider that the necessary subdivision of the work reduces the operating unit to what one engine, or its equivalent will handle at the hump, the objection seems to rest upon no very substantial basis.

Efficiency and economy in operation as a whole will depend finally upon rigid adherence to the operating system; track system and operating system must harmonize and sustain a nice adjustment, but once determined operating methods must control and be adhered to through thick and thin.

On the score of economy the plan proposed seems to possess every advantage. The estimated cost of the clearing yard, with its facilities and equipment, was in round figures, $14,000,000, requiring an initial expenditure of $10,000,000. It was further estimated that the economies the proposed system would effect in switching service alone represented the interest at 4 per cent. on an investment of $20,000,000. This took no account of the release of large areas of land and extensive trackage that

could be devoted to other purposes, nor to many other economies that could not be clearly estimated and possibly not foreseen; but by far the greatest advantage expected from the adoption of the proposed system consisted in relief from periodic congestion, and in relation to this the factor of cost was regarded as secondary. The unit prices that entered into the above estimate are, of course, out of date, but the relative value of the general figures still hold good.

As to the capacity of the clearing yard measured by the estimated flow of traffic through it, to the writer it seems at this distance that it was much underestimated. It was not anticipated that all of the tracks in each of the groups composing it would be constructed at one time of the capacity shown, but that beyond a certain limit the adjustment of the relative capacities of the various yards would be determined by use. Doubtless these factors in the problem sustain a certain definite relation for a given volume and character of business in each particular case, that can be best determined under actual operating conditions.

The length of the various groups of tracks composing this clearing yard was based on a train length of one hundred cars, that requirement being specified. It seems to be excessive and hardly justified by the facts in the case. The length of the yard could be materially reduced with economy in construction and further advantage in operation.

The receiving yard, as shown, is believed to be relatively too large and it could be reduced with advantage. The receiving end is no place to hold cars or allow them to accumulate, and it should be made as small as can consistently be done in any given case. If necessary at any point, cars should be held in made-up trains in the forwarding yard where the responsibility for delay will rest with the forwarding road. Traffic should be kept moving through the receiving yard, and with sufficient capacity at the hump as there is believed to be in this case, this is entirely feasible. In cold weather cars should not be left standing long enough for the packing in the oil boxes to chill, so cars will run hard, and this should fix the limit of time in any case for cars to remain "dead" on receiving yard tracks.

The cable haulage system proposed seems to offer substantial advantages, even if there was no increase in capacity in the number of cars put over the hump in a given time, and with the improvement in electric motors for heavy service, that has taken place in recent years, their use in place of steam would doubtless be much more satisfactory.

It was found that the readjustment of grade lines made possible in this case by the assumed adoption of the cable haulage system resulted in a saving in the cost of construction that fully offset the cost of machinery, together with the necessary concrete structures, and the cost of installation.

There are certain business methods the modification of which would go far to speed up the movement of traffic and reduce or prevent congestion in yards and terminals generally. I refer to the present methods of billing which involve notice through yardmaster and agent to consignee

and return of information through the same channel, and the practice of storing "hold" cars for the convenience of the consignee who handles his business on reconsignment.

In the first instance there would seem to be no good reason why the card bill that accompanies the car should not carry in addition to the usual information all that is needed to make final delivery, with a duplicate for the yardmaster's use, and a triplicate attached to the car. This should be done so that cars can be lined up for delivery in all cases, except those where credit to the consignee has been refused.

In the second instance it is believed that the practice in many places of storing "hold" cars is responsible as much as any one factor for the periodic congestion from which all roads, shippers and consignees suffer alike. From this standpoint there is not a good word to be said for this custom, and with the exception of actual emergencies and cars held for charges it should be everywhere abolished as it has already been in some instances.

Detroit, July 11, 1913.

Appendix.

....................Rail............Company.

STATEMENT.

SHOWING THE MAXIMUM MONTHLY MOVEMENT OF FREIGHT CARS IN THE BUFFALO TERMINAL DISTRICT.

Month of....................19....

	INBOUND		OUTBOUND	
	Loaded.	Empty.	Loaded.	Empty.

A. Total for all routes:
1. Total for home route.
2. Total for foreign routes (Buffalo Interchange).
3. Total for terminal routes (Include lake business).

B. Classify A1 and A2 as follows:
1. Coal.
2. Ore.
3. Grain.
4. Live stock.
5. Refrigerator freight.
6. All other fast freight.
7. Slow freight.

C. Classify A2 by routes (Buffalo Interchange):
1. Erie R. R.
2. Erie R. R.
3. P. R. R.
4. P. R. R.
5. N. Y., C. & H. R. R.
6. W. S. R. R.
7. L. V. R. R.
8. D., L. & W. R. R.
9. L. S. & M. S. Ry.
10. N. Y., C. & St. L. Ry.
11. B., R. & P. R. R.
12. M. C. R. R.
13. G. T. Ry.
14. B. C. R. R.

WHERE HELD

E. Held for reconsignment or to complete trains or cargoes:
1. For north shore rail routes.
2. For south shore rail routes.
3. For lake.
4. How many classes, lots or shipments, and numbers of cars in each.

THE FOLLOWING GENERAL INFORMATION IS ALSO NECESSARY.

Show the limits of the district served by each switching run (not including interchange), and the maximum number of cars handled in each district.

Show the maximum number and kind of empty cars held to fill general orders in the Buffalo terminal district, and where held.

Show the maximum number and kind of empty cars held to fill special orders in the Buffalo terminal district, and where held.

Show the maximum number of cars in process of "coopering," and where held.

Show the maximum number of stock cars held for cleaning, and where held.

Show the number of classifications you will require in making up outbound trains.

REQUIREMENTS AND RESTRICTIONS,

ESSENTIAL IN A GENERAL CLASSIFICATION AND CLEARING YARD.

The principles, requirements and restrictions here laid down were the outgrowth of the investigation concerning the Buffalo freight terminals problem and the design of the clearing yard. They are regarded as essential features in any complete development of this character:

(1) For traffic in opposite directions, two hump yards parallel and cross-connected with the humps as nearly opposite as possible.

(2) Location to permit approach tracks and departure tracks, without grade crossings, with unobstructed view and with gradients not exceeding the ruling grade of the connecting main lines.

(3) General trend of ground line on profile to favor gravity grades—level or rising toward the center, if possible. Surface lines descending toward the center, or similar grade lines of adjacent main tracks that control the situation, are inadmissible.

(4) The yard system, as a whole, to be enclosed by a double line of thoroughfare tracks which may limit a group of yard tracks where convenient; connections to be made at all critical points such as switching leads or the extension of such leads, interior thoroughfare tracks, etc.

(5) Track system to provide for a continuous forward movement of freight traffic, and to be free from grade crossings, except such as are necessarily made by slip switches, etc.

(6) All groups of yard tracks to have double leads, and the exterior tracks in every case to be reserved for use as thoroughfare tracks only.

(7) Duplication of hump tracks to insure continuous movement in classifying cars, and prevent complete stoppage in case of derailment.

(8) Clearing yard to be composed of:
(a) Receiving yard, receiving section and hump section.
(b) Hump tracks.
(c) Scale tracks.
(d) Classification yards, subdivided to hold cuts of cars to be built up into trains in a predetermined order.
(e) Repair yards, consisting of holding section, repair section and section for finished cars.

(9) Caboose yard for putting caboose on train before movement.

(10) Forwarding yard.

(11) Second caboose yard for putting caboose on train as it pulls out.

(12) Independent loop tracks for road engines providing for a continuous forward movement to engine yard, turning the engines without the use of turntable, and a continuation of these tracks beyond the engine yard to point of attachment for outgoing trains.

(13) Engine yard arranged to classify engines by roads and class of engines. Ash pits, coal, sand and water supply with facilities for thawing out arranged in order approaching the engine yard.

(14) Special provision for coal, sand and water supply for hump engines, near or at the hump.

(15) Roundhouse adjacent to engine yard equipped for light repairs to dead engines only.

(16) Coal storage yard for coal on cars, stock pile and trestle and chutes for coaling engines.

(17) General water supply system, with storage reservoir and standpipe.

(18) Centrally located plant for light, heat and power purposes.

(19) System of fire protection, including apparatus on cars, and on engines.

(20) Telegraph and telephone systems.

(21) Pneumatic tube system.

(22) Trolley tracks and cars for car-riders.

(23) Foot bridges for car-riders across forwarding yard.

(24) Signal system and lighting system.

(25) Ice houses with re-icing and filling facilities.

(26) General office building and outlying buildings for yardmasters. inspectors, repairmen and rest rooms and bunk houses for enginemen and trainmen.

(27) Stock yards, including:
(a) Unloading tracks, platforms and feeding pens with cement floors.
(b) Separate facilities for loading and forwarding stock.
(c) Yards for cleaning and disinfecting empty stock cars.
(d) Yards for holding empty stock cars after cleaning.
(e) Water supply and special appliances for fire protection.
(f) Isolated pens and other facilities for quarantine purposes.

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EXTRA TOP WIDTH FOR NEW FILLS.

By J. C. L. FISH, Professor of Railroad Engineering, Stanford University, California.

In order that the settled fill may be of standard top width, the new fill must be made extra high to offset vertical settlement and extra wide on top to offset sliding of the material on the shoulders. Thus in building any fill two questions arise: (1) to what extra height shall the fill be made, and (2) what extra top width shall be given to the fill?

Tables of vertical shrinkage allowance are given in several books which treat of earthwork. The Manual of 1911, page 35, gives the following under the caption "Allowance for Shrinkage in Embankments":

> For green embankments, shrinkage allowance should be made for both height and width.

And then gives a short table of additional heights to offset vertical settlement, but makes no specific recommendation as to the amount of extra width. The writer recalls only two definite statements as to extra width to be given to new fills. The late Augustus Torrey made the following statement before this Association:*

". . . Our practice on the Michigan Central is to widen the base of the embankment one foot additional to what the uniform width would make it—one foot for every five feet in height of the embankment. We generally build a trifle above grade, but always wide. . . ."

Mr. L. B. Merriam states† that on the reconstruction of the Union Pacific Railroad he built fills to subgrade and gave each fill a top width determined thus (Fig. 1):

". . . The slopes were steepened until the top width of the embankment at subgrade was the same as if the embankment had been built

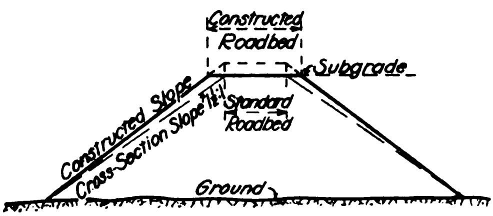

FIG. 1.

to a height above subgrade, equal to the percentage of its height which the method of construction warranted, and then cut down to subgrade. . . ."

*Proceedings American Railway Engineering Association, Vol. 3 (1902), pp. 36 and 37.

†Engineering News, Jan. 3, 1901 (Vol. 45, p. 11).

The following is offered as a rational method of determining the extra top width to be given to a new fill under any conditions. This method was devised by the writer for use on high fills, where it proved entirely satisfactory.

For the present purpose we distinguish (I) fills built upon ground which is level transversely, and (II) fills built upon ground which has considerable transverse slope. In each of these groups there are three cases to be considered: A fill may be built (a) with partial vertical shrinkage allowance with the expectation that it will settle below subgrade; or (b) with full vertical shrinkage allowance so that it will settle just to subgrade; or (c) just to subgrade so that the top will drop below subgrade to the full extent of the vertical settlement.

(I) *Extra top width for new fill built upon ground having little or no transverse slope.* (a) The conditions are shown in Fig. 2. Subgrade height is h. The fill is built to the height h' (greater than h) with

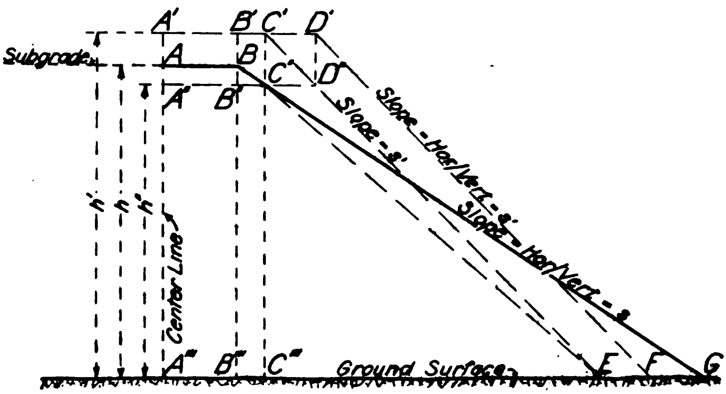

FIG. 2.

the expectation that it will settle to the height h'' (less than h). The slope ratios are s for the settled fill and s' for the new fill, the ratio in each case being horizontal/vertical.

If the shoulder of the new fill were at B', the shoulder of the settled fill would be at B'', provided there were no sliding; but at the elevation of B'' the half width of the fill should be $A''C''$. Therefore the shoulder of the new fill should be carried out from B' to C', even if there were no sliding of the shoulder. With the shoulder of the new fill at C', the toe would be at E ($C'E$ being drawn with slope s'), and, providing there were no sliding, the side line of the settled fill would be $C''E$. However, the shoulder will not be stable at C'' unless the triangle $C''EG$ be filled. To fill this triangle requires an additional slab of material, $C'D'FE$, on

the side of the new fill. The area of the slab, settled, is $h'' \ C'D'$, and this must be equal to the area of the triangle $C''EG$. Therefore,

$$h'' \ C'D' = \tfrac{1}{2} h'' \ EG,$$

or

$$\begin{aligned} C'D' &= \tfrac{1}{2} EG \\ &= \tfrac{1}{2}(C'''G - C'''E) \\ &= \tfrac{1}{2}(h''s - h's') \quad \text{.................} (1) \end{aligned}$$

The total extra top width to be added to the standard roadbed width on each side of the fill is therefore

$$\begin{aligned} B'D' &= B'C' + C'D' \\ &= (h - h'')\, s + \tfrac{1}{2}(h''s - h's') \quad \text{.......} (2) \end{aligned}$$

since $B'C' = (h - h'')s$.

(b) For the fill which is built with full shrinkage allowance, $h'' = h$, $h - h'' = 0$, and eq. 2 reduces to

$$B'D' = \tfrac{1}{2}(hs - h's' \quad \text{.......................} (3)$$

(c) For the fill which is built new just to subgrade $h' = h$, and eq. 2 becomes

$$B'D' = (h - h'')s + \tfrac{1}{2}(h''s - hs') \quad \text{...............} (4)$$

In practice h and h' are known and s' can be measured readily, but, owing to the fact that the vertical settlement and final slope of the fill must be estimated, the values given to h'' and s are subject to some uncertainty. Hence the engineer must use the foregoing formulas with judgment, increasing the computed extra top width if material be abundant or suspected of treacherous action in the fill.

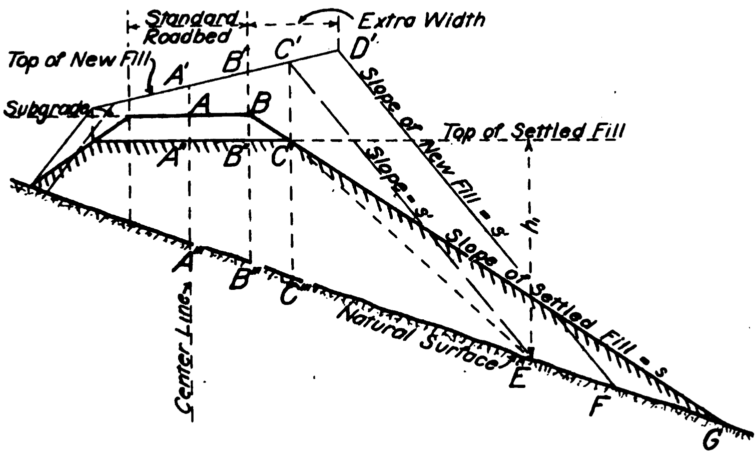

FIG. 3.

(II) *Extra top width for new fill built upon ground having considerable transverse slope.*—In order that the top of a fill that is built on a transverse slope may be level at the end of settlement the top of the new

fill must have some slope in the direction contrary to the slope of the ground. See Fig. 3, which is drawn for case (a) in which the new fill is made with partial shrinkage allowance for vertical settlement. Since the fill is higher on one side than the other the extra top width required will not be the same for the two shoulders. To find the extra top width required for the shoulder on the downhill side of the fill we proceed as follows:

(1) Plot A' on the cross-section to represent the top of the new fill on the center line.

(2) Plot A'', $A'A''$ being the vertical settlement expected on the center line.

(3) Draw a horizontal through A'' *to cut* BG at C''.

(4) Plot C' vertically above C'', making $C''C' = C''C''' \; (A''A'/A''A''')$.

(5) Draw $C'E$ through C' with the slope s' of the new fill.

(6) Find, by scaling, the approximate (settled) height h_1 of the slab $C'D'FE$, which is required to fill triangle $C''EG$.

(7) Find the area of the triangle $C''EG$.

The required width of slab $C'D'FE$ is (approximately)

$$C'D' = (\text{area of triangle } C''EG)/h_1 \dots\dots\dots\dots\dots (5)$$

and

$$B'C' = AA''s \text{ (approximately)} \dots\dots\dots\dots\dots\dots (6)$$

Therefore the extra top width to be given the downhill side of the fill is (approximately)

$$B'D' = AA''s + (\text{area of triangle } C''EG)/h_1 \dots\dots\dots\dots (7)$$

The extra top width on the uphill side of the fill is found in the same way.

(b) and (c). When the new fill is to be built with full shrinkage allowance for vertical settlement, or to subgrade, the general method given above is used to determine the extra top width required at each shoulder.

EXAMPLES OF FILLS BUILT ON GROUND LEVEL TRANSVERSELY.

Example 1.—The subgrade height of a new fill at a given station is 60 ft. New side slope is 1.25:1 and the settled side slope is expected to be 1.5:1. The vertical shrinkage allowance is judged to be 10 per cent., but it is decided to build the fill only 2 ft. above subgrade. What should be the extra top width at each shoulder of the new fill? The answer is found by eq. 2, thus:

$$\begin{aligned} B'D' &= (h - h'')s + \tfrac{1}{2}(h''s - h's') \\ &= (60 - 56.4^*)\ 1.5 + \tfrac{1}{2}(56.4 \times 1.5 - 62 \times 1.25) \\ &= 5.4 + 3.5 = 8.9 \text{ ft.} = 9 \text{ ft., say.} \end{aligned}$$

Thus the total extra top width is twice 9.25, or 18.5 ft.

*Since $h' = 1\,10\, h''$, $h'' = .91\, h' = .91\, h' = .91 \times 62 = 56.4$.

Example 2.—If it be decided to build the fill of Example 1 to subgrade height plus full shrinkage allowance the extra width required at each shoulder will be (eq. 3)

$$
\begin{aligned}
B'D' &= \tfrac{1}{2}(hs - h's') \\
&= \tfrac{1}{2}(60 \times 1.5 - 66 \times 1.25) \\
&= 3.75 \text{ ft.};
\end{aligned}
$$

and the total extra top width will be 7.5 ft.

Example 3.—Suppose the fill of Example 1 to be built to subgrade. In that case

$$
\begin{aligned}
B'D' &= (h - h''s + \tfrac{1}{2}(h''s - hs') \\
&= 60 - 54.6)\ 1.5 + \tfrac{1}{2}(54.6 \times 1.5 - 60 \times 1.25) \\
&= 11.6;
\end{aligned}
$$

and the total extra top width required is $2B'D'$, or 23 ft., say.

The results obtained by formula should be used not blindly, but with judgment.

DISCUSSION.

F. L. Wheaton, Delaware, Lackawanna & Western Railroad:

This is a very clever mathematical solution of a problem which does not admit of mathematical treatment. Theoretically, this solution is excellent, but I fear in practice the factors entering into the formula are so uncertain as to be of little practical use to the construction engineer. Many of these factors are impossible to determine until the fill has been actually constructed and depend upon the nature of the ground upon which the fill is placed, the height of fill, the nature of the material of which it is composed and method of construction.

As Mr. Fish says in his concluding clause, the results of this formula should be used not blindly, but with judgment and, since so much depends upon good judgment, it would seem to me that the whole matter should be left entirely to the judgment of the engineers in charge.

I do not think that a formula of this kind should be inserted in the Manual, since the tendency would be for young and inexperienced engineers to use it wrongly.

C. S. Millard, Cleveland, Cincinnati, Chicago & St. Louis Railway:

It seems to me that Mr. Fish has handled the subgrade very thoroughly and has adopted a rational method of determining the extra top width, which should prove satisfactory in the great majority of instances.

Paul Didier, Baltimore & Ohio Railroad:

In perusing the article and looking over the blueprints carefully, I concur with his views as to Figs. 1 and 2, but the extra fill, as shown in Fig. 3, appears to be rather extravagant.

R. C. Falconer, Erie Railroad:

I have glanced over this paper in a hasty manner, and while I have not followed his equations through, the method seems rational and proper with this one exception:

It depends on the use of two slopes, a slope s, which is the final slope taken of the embankment, and the slope s', which is the slope of the new embankment immediately after it is completed.

Materials vary, and while it is perfectly possible to measure the slope s', it is possible not to know during construction just what the slope s will be after the bank has taken its entire settlement. The equation then necessitates the assumption of the slope s, and the results are dependent entirely on the judgment of the engineer, as they are without the use of the formula.

H. J. Slifer, Consulting Engineer:

I had hoped to be able to answer your letter of March 11th, relative to Professor Fish's paper before the meeting of the Association; but was so busy that I could not find time to do so. I intended to discuss the subject with you during the meeting of the Association, but was unfortunately prevented from being present on the day that the Roadway Committee's Report was considered. I am, therefore, writing you my views, which have been very considerably changed in the past five years, and particularly so through my experience in rebuilding the Panama Railroad, where we found it necessary to establish new rules and regulations, none of which could be made standard for all conditions to offset the unheard of settlement of material in railway embankments. In fact, I concluded after a more than 20 years' experience as a Railroad Engineer, that I was an "infant" in knowledge on this subject after I spent a few months on the Isthmus of Panama.

There is a nicety in the theoretical and technical views of engineers, as it applies to some subjects, that fits the particular experience of other engineers in the field, but there are some things in which engineer's "horse sense" will have to guide his work, and I think this applies particularly to the question of the settlement of new fills.

It has been my general practice to follow the rules which are used by Mr. Merriam on reconstruction of the Union Pacific Railroad; but, even following such rules, I have had more than one occasion where I found it necessary to use a gang of trackmen to lower a new fill before the track could be laid on it—which, naturally, was an indication that this rule would sometimes fail.

In noting Prof. Fish's paper, I see that he indicates that there have only been two definite statements made as to the extra width that should be given to new fills. I would respectfully call attention to copy of a letter which I wrote in 1906, and which is quoted on page 307, Vol. 8. Proceedings, 1907, Roadway Committee Report, American Railway Engineering and Maintenance of Way Association. I can't say that the rules

or suggestions, as shown in this letter, were ever followed, or how the future years or sliding may have confirmed the percentages.

I do not think that any engineer would deliberately make a new fill with the idea that it should settle below subgrade, unless it was an oversight or done for the purpose of topping the subgrade with a bed of sand or something of a similar character. So that I feel that Example A should certainly be eliminated, and in fact I think Example C could also be very readily eliminated from consideration, as it is the usual rule of engineers to build new embankments, as shown in Example B, "with full vertical shrinkage allowances so that it will settle just to subgrade."

I do not believe that a practical engineer in the field would use the suggested rules if they were printed and adopted, and I would hesitate to recommend any such action, for the reason that I feel that the question of shrinkage of new banks is very largely one of "guess work," and like the question of "area of waterways," the engineer would usually build his waterway twice as large as the formula would provide so as to be on the safe side, and in this connection I note particularly that Prof. Fish indicates that the values given to the basic measurements are "uncertain and that the formula should be used with judgment."

J. E. Willoughby, Atlantic Coast Line:

The paper is interesting since it undertakes by mathematics to determine the extra width to be given to fills to provide for "side shrinkage," but inasmuch as in shrinking a fill does not follow any mathematical laws, it occurs to me that the Roadway Committee could do no more than submit the paper as an ingenious discussion of a condition for which there is but little hope of ever finding a mathematical formula. It has been my experience with fills that they will not settle uniformly. They almost invariably settle in holes and while, as a whole, to approximately the amounts shown by the recommendations of the Roadway Committee as published in the Manual of 1911, there are always portions of the fill which fall but little below the elevation at which the material was dumped. I have abandoned the practice of finishing a high fill above subgrade on a maximum grade of a low-grade line railway, because the shrinking of the fill takes place unevenly, and I have had the annoyance of having, after the railway was put into operation, projections above subgrade on high fills constructed for low-grade line railways. The practice which I have adopted is that, during the progress of construction of the fill, I place sufficient material above subgrade to insure that, when the time comes for constructing the finished roadbed ready to receive the ballast, the fill would be of sufficient height to finish the roadbed to exact subgrade elevation. All projection above this elevation is cut away.

I find that as a general rule that if the width of the fill at subgrade be increased in feet an amount equal to about 10 per cent. of the height of the top of the fill above the surface of the earth, then a sufficient width will be obtained to provide for the standard width of roadbed at sub-

grade height when the fill has ceased to shrink. For example for a fill 40 ft. in height, I make the new fill four feet wider at subgrade than the standard width requires.

Where fills are at the foot of two grades, or where the grade is less than the maximum grade, I make the roadbed height sufficient to provide for shrinkage to the extent as is shown by the Manual of 1911, considering always the amount of shrinkage that has taken place during the construction period.

Alfred C. Prime, Pennsylvania Railroad:

I would say that the theory as worked out by Prof. Fish is very interesting and instructive, but that in actual practice his formulæ should be used with great care on account of varying natures of the material encountered in making fills, and the difference in climatic conditions in various parts of the country.

S. B. Fisher, Missouri Kansas & Texas Railway System:

I think this is a very creditable discussion of the question, from a theoretical standpoint, and is useful in enabling one to understand the principles involved. The assumption in such discussions is that the earth settles uniformly, according to fixed laws. The trouble in doing the work is that the fills do not settle uniformly, but very irregularly. Some places it scarcely subsides at all, and at other places it goes down beyond all expectations.

COMMENTS BY THE AUTHOR.

J. C. L. Fish:

I shall answer the criticisms made by some members of the Committee on Roadway, point by point, in an impersonal way.

(1) In Figs. 1, 2 and 3 the allowance for shrinkage and the extra top width are much exaggerated for the sake of clearness. The drawings are not made to scale, but are mere diagrams.

(2) It would appear that some who discussed my paper had the impression that the formulas were worked out for the sake of a little exercise in mathematics. The fact is, I investigated the subject when, as Engineer on Construction with the Lake Shore & Michigan Southern Railway, I was building fills ranging in height to 120 ft.; and for nearly four years I used the method described in my paper on such fills. The first draft of the paper was made during the third year's use, with the idea of presentation to this Association, but through lack of time and neglect the final draft was deferred for five years. The subject was investigated and the principle found and used within the limits of the right-of-way—all by an engineer responsible for results.

(3) The method offered in my paper is entirely rational, notwith-

standing that one of the factors, *s*, must be estimated, according to my understanding of the word rational.

(4) The slope, *s*, which a bank, of given materials and given method of construction, will take on settlement can be closely predicted by the engineer who has opportunity to measure the slopes of settled fills which have been made of like material with like method; and in the great majority of cases such opportunity exists. On the contrary, comparatively few engineers have the opportunity of knowing the original dimensions of fills which have settled. It follows that the experience necessary to form trustworthy judgment as to what slope, *s*, a fill will take on settlement, is in general much more readily obtainable than the experience necessary to form trustworthy judgment as to the extra top width to be given to a new fill. Furthermore, common experience shows that, all things equal, skill in estimating simple quantities is more readily acquired than skill in estimating complex functions of simple quantities. For example, one can more quickly become skillful in estimating heights and lengths of fills than in estimating their volumes. To make the best possible estimate of the total cost of a proposed railroad the engineer uses his best judgment on each of the elements of cost, and then combines the estimated elements. Few engineers would advance the idea that since one must use his judgment on each element in this case, he might as well ignore the elements and proceed at once to judge the total cost.

(5) The formulas offered in the paper cannot be classed with waterway formulas, for the reason that waterway formulas, while containing the elements, drainage area and slope, which can be measured or even estimated satisfactorily, contain a coefficient for the proper value of which for given cases we are still seeking. If the waterway depended only upon slope and drainage area, it is difficult to believe that an engineer would prefer to fix the waterway in a given case by direct judgment rather than by computation from the elements slope and drainage area, even if the two elements had to be estimated.

(6) There are many useful and much-used formulas which give results which must be used with judgment. For example, do we not fix the size of water pipe for given flow under given head by formula? Yet the formula involves the coefficient of friction of the proposed pipe, and this coefficient must of necessity be estimated, and consequently the result obtained by the formula must be used with judgment. I take it that even the shrinkage allowances now recommended by this Association are intended to be used with judgment. Surely the caution that the results obtained by the method of my paper should be used with judgment cannot be used as a basis for condemning the method.

I appreciate the consideration which the members of the Roadway Committee have given my paper, and hope they will be interested in my replies to their criticisms. In conclusion, I wish to thank Mr. Slifer for

calling my attention to his letter (Vol. 8, page 307, Proceedings American Railway Engineering and Maintenance of Way Association) on extra top width for new fills.

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THE SALES METHOD OF APPRAISING REAL ESTATE. *Engineering and Contracting*, v. 35, p. 751 (June 28, 1911). (Statement to the Wisconsin State Railroad Commission of the use of this method made by W. D. Pence; one and one-half pages.)

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——Abstract. Doherty on Electrical Rates and Franchises. *Electrical World*, v. 52, pp. 170, 352 (July 25, Aug. 15, 1908).

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——Editorial. Depreciation. *Electrical World*, v. 60, p. 909 (Nov 2, 1912)

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ADEQUATE DEPRECIATION OF CAPITAL EXPENDITURE BY MUNICIPAL ELECtricity Undertakings; by J. Horace Bowden and Fred Tait. *Electrical Review* (London), v. 60, pp. 1021, 1064 (June 21, 28, 1907). (Serial giving full discussion of the subject, including physical valuation.)

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ESTIMATING THE COST OF AN ELECTRIC PLANT. *Journal*, Franklin Institute, v 165, p 397 (May, 1908). (Gives years of life as estimated by different engineers for various parts of the plant.)

MAKING RATES FOR ELECTRIC PLANTS; by Halford Erickson. *Public Service Regulation*, v. 1, p. 579 (Sept., 1912) (Principles of valuation; going value, depreciation, operating expenses, rates, effect of demand on cost, etc.)

THE OBSOLESCENCE OF ELECTRIC LIGHTING PLANT; by F. Fernie. *Electrical Review* (London), v. 63, p. 516 (Sept. 25, 1908) (Discusses rate of depreciation and necessity for an insurance fund.)

RATE-MAKING FOR PUBLIC UTILITIES; by Halford Erickson. *Electric Railway Journal*, v 33, p. 775 (April 24, 1909) (Relation between investment and output of electrical plants; paper read before the Wisconsin Electric and Interurban Railway Association.)

RATE REGULATION OF ELECTRIC POWER; by S. S. Wyer. *Cassier's Magazine*, v 35, p. 410 (Jan., 1909). (Considers replacement value and depreciation.)

RATES AND RATE MAKING; by John F. Druar. *Journal*, Association of Engineering Societies, v. 50, p. 221 (May, 1913). (Discusses the valuation of a combined electrical and gas property to determine the legitimate capital, on which capital a certain return should be received.)

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS, p. 668. Edition 3. McGraw-Hill Book Co., New York, 1910 (Contains brief data on cost and depreciation of electric plants.)

UNIFORM SYSTEM OF ACCOUNTING. (Letter), by F. E. Haskell. *Electrical World*, v. 53, p 928 (April 15, 1909). (Rule adopted to provide for monthly charge to cover wear and tear, obsolescence and inadequacy, etc.)

UPKEEP CHARGES ON LARGE ELECTRIC GENERATING SETS; by Robert J. Burstall. *Electrical Engineer* (London), v. 39, p. 866 (June 21, 1907) (Paper read before the Engineering Conference, Institution of Civil Engineers; allowance for repairs and renewals.)

——*Engineering*, v. 83, p. 834 (June 21, 1907)

VALUATION OF ELECTRIC PLANTS. (Editorial.) *Engineering Record*, v 58, p 365 (Oct. 3, 1908). (One and one-half columns.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES.

Aberdeen, Scotland.

ABERDEEN AND DEPRECIATION. *Municipal Journal* (London), v 12, p. 943 (Oct. 23, 1903). (Comparison of allowance for depreciation of electrical plants at Aberdeen, Glasgow, and Bolton.)

Beloit, Wis.

*CITY OF BELOIT VS. BELOIT WATER, GAS AND ELECTRIC COMPANY; Decided July 17, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 7, p. 216. Madison, Wis., 1912 (Details of the valuation of the power plant and going value.)

FIXING NORMAL OPERATING COSTS; by Frank A. Newton. *Engineering Record*, v 65, p. 258 (March 9, 1912). (Comments on the decision of the Wisconsin Railroad Commission in the case of the City of Beloit vs Beloit Water, Gas & Electric Co.)

Boonville, N. Y.

AMORTIZATION RULE OF THE NEW YORK PUBLIC SERVICE COMMISSION OF the Second District. *Electrical World*, v. 54, p. 1162 (Nov. 11, 1909). (Computation of amortization of property of the Board of Light Commissioners of Boonville, N. Y.)

Bristol, England.

REPORT BY SIR WILLIAM PREESE ON PROBABLE LIFE OF PLANT AT BRISTOL. *Electrician*, v. 57, p. 704 (Aug. 17, 1906) (Details of estimated life of electrical plants; figures given for various items are those used by L. R Dicksee in his report.)

——Editorial. Depreciation. *Electrician*, v. 57, p. 702 (Aug. 17, 1906)

Burkhardt Milling & Electric Power Co.

*E. G. ROSS ET AL. VS. BURKHARDT MILLING AND ELECTRIC POWER COMpany; Decided April 8, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 139. Madison, Wis., 1911. (The value of property and the method of determining values are discussed.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

California.

***UNIFORM CLASSIFICATION OF ACCOUNTS FOR ELECTRIC CORPORATIONS** prescribed by the Railroad Commission of the State of California; Adopted Oct. 23, 1912, Effective Jan. 1, 1913. Sacramento, 1912.

Cardiff, Wales.

DEPRECIATION: INTERESTING REPORT FROM CARDIFF. *Municipal Journal* (London), v. 16, p. 1083 (Dec. 20, 1907). (Allowance for depreciation considered to represent fair wear and tear.)

DEPRECIATION OF CARDIFF ELECTRIC TRAMWAY AND LIGHTING UNDER-takings. *Electric Railway Review*, v. 19, p. 16 (Jan. 4, 1908). (Details of rates of depreciation of equipment are given.)

Cashton, Wis.

***IN RE DETERMINING AND FIXING JUST COMPENSATION TO BE PAID TO THE** Cashton Light and Power Company by the Village of Cashton for the Taking of the Property of the Said Company Actually Used and Useful for the Convenience of the Public in Accordance With the Provisions of Chapter 499, Laws of 1907; Submitted Oct. 14, 1908, Decided Nov. 28, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 67. Madison, Wis., 1910. (Discusses going value of public utility plants.)

Chippewa Falls, Wis.

***T. J. CUNNINGHAM ET AL. VS. CHIPPEWA FALLS WATER WORKS AND** Lighting Company; In Re Investigation by the Railroad Commission of Wisconsin of Rates Charged by the Chippewa Falls Water Works and Lighting Company; In Re Valuation of the Property of the Chippewa Falls Water Works and Lighting Company; Decided June 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 302. Madison, Wis., 1911. (Contains data on the value of the electric plant.)

Chippewa Valley Ry., Light & Power Co.

***IN RE APPLICATION OF THE CHIPPEWA VALLEY RAILWAY, LIGHT AND** Power Company for Authority to Change its Rates; Submitted Feb. 19, 1908, Decided Mar. 18, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 311. Madison, Wis., 1909. (Refers to valuation of electric plant.)

Darlington, Wis.

***IN RE APPLICATION OF THE DARLINGTON ELECTRIC LIGHT AND WATER** Power Company for Power to Increase Rates, In Re Darlington Electric Light and Water Power Company, Valuation of Property; Submitted Sept. 2, 1909, Decided June 17, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 397. Madison, Wis., 1911.

District of Columbia.

***UNIFORM SYSTEM OF ACCOUNTS FOR GAS CORPORATIONS AND ELECTRIC** Corporations in the District of Columbia as Prescribed by the Interstate Commerce Commissior. pp. 29, 47, 55, 67. Washington, 1909. (Provision for amortization of plant, which includes monthly charges of the amount estimated to be necessary to cover wear, tear and obsolescence.)

Dodgeville, Wis.

***CITY OF DODGEVILLE VS. DODGEVILLE ELECTRIC LIGHT AND POWER COM-**pany, Submitted May 4, 1908, Decided June 2, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 392. Madison, Wis., 1909 (Data relating to valuation of plant.)

Edinburgh, Scotland.

DEPRECIATION, ETC., ON ELECTRICITY SUPPLY UNDERTAKINGS. *Electrician*, v. 57, pp. 231, 350 (May 25, June 15, 1906) (Report on present condition of electric light and machinery plant of the Edinburgh Corporation.)

Fareham, England.

DEPRECIATION. (Editorial.) *Electrician*, v. 62, p. 709 (Feb. 19, 1909). (Depreciation in connection with a loan for an electrical plant at Fareham, England.)

Greenwood, Miss.

REPORT OF THE APPRAISERS SELECTED TO ESTIMATE THE VALUE OF property of the Greenwood Light and Water Company to the City of Greenwood and the Greenwood Light and Water Co., March 22, 1904. Greenwood, Miss., 1904. (Eight pages.)

Groton, Mass.

A VALUABLE MUNICIPAL RATE DECISION. (Editorial.) *Engineering Record*, v. 66, p. 2 (July 6, 1912). (Comments on decision by the Massachusetts Gas and Electric Light Commission on electrical rates at Groton, Mass; very brief.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(Continued).

Kaukauma, Wis.

*IN RE DETERMINING AND FIXING THE JUST COMPENSATION TO BE PAID to the Kaukauma Gas, Electric Light and Power Company by the City of Kaukauma; Submitted Feb. 6, 1911, Decided Dec. 26, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 409. Madison, Wis., 1912. (Physical value and going value of the property and value of the water-power lease.)

La Crosse, Wis.

*IN RE APPLICATION OF THE LA CROSSE GAS AND ELECTRIC COMPANY FOR Authority to Increase Its Rates; Decided Nov. 17, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, pp. 138, 156, 170, 179, 202, 224. Madison, Wis., 1912. (Physical value of plants, original cost and effect of allowance of going value.)

*IN RE APPLICATION OF THE LA CROSSE GAS AND ELECTRIC COMPANY FOR Authority to Increase Rates; Submitted Aug. 16, 1907, Decided Sept. 19, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 3. Madison, Wis., 1909. (Gives method of estimating cost of plant before physical examination can be made.)

*THE MEANING OF "ACTUAL STATION OPERATING COSTS." *Engineering Record*, v. 65, p. 191 (Feb. 17, 1912). (Decision of the Railroad Commission of Wisconsin in the case of the La Crosse Gas & Electric Co.)

Madison, Wis.

RATE MAKING FOR PUBLIC UTILITIES, THE MADISON CASE; by Percy H. Thomas. *Electric Journal*, v. 7, p. 560 (July, 1910). (Discusses the decision of the Railroad Commission of Wisconsin in the case of the State Journal Printing Co. *vs.* the Madison Gas & Electric Co., rendered March 8, 1910.)

Manitowoc, Wis.

*CITY OF MANITOWOC VS. MANITOWOC ELECTRIC LIGHT COMPANY; Submitted Sept 30, 1908, Decided June 14, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 361. Madison, Wis., 1911. (A tentative valuation of the physical property of the respondent was made; the income accounts and operating expenses for a term of years are analyzed.)

Marinette, Wis. See Menominee, Wis.

Marquette, Mich.

A STUDY IN CENTRAL-STATION FINANCES AND OPERATION FROM MARQUETTE, Mich. *Electrical World*, v. 53, p. 403 (Feb. 11, 1909). (Gives estimates of depreciation for an electric light and power plant.)

Massachusetts.

DISTRIBUTION COSTS IN SEVEN CENTRAL-STATION SYSTEMS. *Electrical World*, v. 52, p. 1014 (Nov. 7, 1908). (Figures deduced from returns to the Massachusetts Board of Gas and Electric Light Commissioners.)

Menominee, Wis.

*IN RE VALUATION OF ELECTRIC LIGHT PLANT OF MENOMINEE AND MARInette Light and Traction Company. In Re Application of Menominee and Marinette Light and Traction Company for Authority to Equalize Rates; In Re Menominee and Marinette Light and Traction Company, Investigation of Rates on Motion of the Commission; Decided Aug. 3, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 778. Madison, Wis., 1910. (Data on valuation of electric light and power plant.)

Merrill Ry. & Lighting Co.

*IN RE APPLICATION OF THE MERRILL RAILWAY AND LIGHTING COMPANY for Authority to Change Its Rates for Electric Lighting; Submitted Sept. 17, 1907, Decided Dec. 10, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 148. Madison, Wis., 1909. (Discusses value of the plant, including water power and dam, electric light plant, and railway plant.)

Minneapolis, Minn.

ELECTRIC RATES FOR MINNEAPOLIS, A LONG CONTROVERSY OVER BASING Rates on Expert Analysis or Unreasonable Comparisons; by William G. Deacon. *Public Service*, v. 5, p. 107 (Oct., 1908). (Contains very brief data on valuation.)

MINNEAPOLIS LIGHT AND POWER RATES. *Electrical World*, v. 51, p. 651 (March 28, 1908). (Brief data on the elements of cost of plant.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

New York City.

ACCOUNTING FOR DEPRECIATION; by H. M. Edwards. *Electric Railway Journal*, v. 37, p. 972 (June 3, 1911). (Method used by the New York Edison Co.)

REGULATED ELECTRIC LIGHT ACCOUNTING; by H. M. Edwards. National Electric Light Association, Thirty-fifth Convention, 1912, Papers, Reports and Discussions, v. 4, p. 106. (On the uniform system of accounts for electrical corporations as prescribed by the Public Service Commission, State of New York, First District, and the petition to modify it.)

— — Abstract. *Electric Railway Journal*, v. 39, p. 1029 (June 15, 1912).

New York State.

NEW YORK PUBLIC SERVICE COMMISSION TENTATIVE ACCOUNTS FOR ELECtrical and Gas Corporations. *Electric Railway Review*, v. 19, p. 532 (May 2, 1908). (Classification for accounts prepared by W. J. Meyers; abstract of some features of the system.)

PETITION FOR CHANGES IN TREATMENT OF DEPRECIATION IN NEW YORK. *Electrical World*, v. 58, p. 1420 (Dec. 9, 1911). (Petition filed by various lighting companies with New York Public Service Commission, Second District; one page.)

STANDARD ACCOUNTING CONFERENCE. *Progressive Age*, v. 26, p. 267 (May 1, 1908). (On report of classification of accounts, gas and electric companies, by the Public Service Commission, State of New York, Second District.)

***STATE OF NEW YORK, SECOND ANNUAL REPORT OF THE PUBLIC SERVICE** Commission, Second District, for the Year Ending Dec. 31, 1908; v. 2. Uniform System of Accounts. Albany, 1909. (Classification of accounts for street railroads, gas and electrical corporations; general amortization account, including amount estimated for wear, tear and obsolescence of plant.)

Pacific Gas & Electric Co.

PACIFIC GAS RATE VALUATION; by John A. Britton. *Progressive Age*, v. 30, p. 330 (April 15, 1912). (Includes cost of electric energy, depreciation and administration.)

Pasadena, Cal.

PASADENA MUNICIPAL LIGHTING PLANT. *Municipal Engineering*, v. 44 p. 505 (June, 1913). (Capitalization, depreciation allowance, etc., in relation to rate regulation.)

Red Cedar Valley, Wis.

***IN RE APPLICATION OF THE RED CEDAR VALLEY ELECTRIC COMPANY FOR** Authority to Increase its Rates; Decided June 14, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 717. Madison, Wis., 1912. (Contains Company's statement of the value of the physical property of the plant.)

Ripon, Wis.

***CITY OF RIPON VS. RIPON LIGHT AND WATER COMPANY**; Decided March 28, 1910. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 5, p. 1. Madison, Wis., 1911. (Data on vaulation of the water, light and electric plants.)

St. Louis, Mo.

REPORT OF ST. LOUIS PUBLIC SERVICE COMMISSION TO THE MUNICIPAL Assembly of St. Louis on Rates for Electric Light and Power. St. Louis, 1911. (Contains description of methods of appraisal of the property of the Union Electric Light & Power Co.)

San Francisco, Cal.

UNIT GENERATING AND DISTRIBUTION COSTS OF THE PACIFIC GAS & ELECtric Company in San Francisco. *Electrical World*, v. 59, p. 790 (April 13, 1912).

Sheboygan, Wis.

***CITY OF SHEBOYGAN VS. SHEBOYGAN RAILWAY AND ELECTRIC COMPANY;** Submitted Oct. 18, 1910, Decided Feb. 3, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 353. Madison, Wis., 1912. (Company's estimate of investment and annual expenses chargeable to street lighting.)

Superior Water, Light & Power Co.

***ESTIMATING THE RATE OF "REASONABLE RETURN" FOR A PUBLIC UTILITY.** *Engineering and Contracting*, v. 39, p. 482 (April 30, 1913). (Argument submitted to the Wisconsin Railroad Commission, for the Superior Water, Light & Power Co., giving analysis of the rate of fair return for capital invested.)

ELECTRIC LIGHT AND POWER—SPECIAL CASES—(*Continued*).

*PUBLIC SERVICE COMMISSION NEWS. *Electrical World*, v. 60, p. 1186 (Nov. 30, 1912). (Basis of valuation of electric plant in investigation of the revenues of the Superior Water, Light & Power Co.)

Wakefield, Mass.

DEPRECIATION OF MUNICIPAL LIGHTING PLANTS. (Editorial.) *Electrical Review and Western Electrician*, v. 53, p. 493 (Oct 3, 1908). (Inadequacy of allowance for depreciation in plant at Wakefield, Mass.)

Waupaca, Wis.

*IN RE JOINT APPLICATION OF THE WAUPACA ELECTRIC LIGHT AND RAILway Company and the City of Waupaca to the Effect that the Railroad Commission Act as Arbitrator in Certain Matters Pertaining to Street Lighting in the City of Waupaca; Submitted Dec. 15, 1910, Decided Feb. 21, 1912. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 586. Madison, Wis., 1912. (Total reproduction cost, present value and cost of operation were ascertained and apportioned between street lighting and all other service.)

West Ham, England.

IS DEPRECIATION AS SUCH, NEEDED? (Editorial.) *Municipal Journal* (London), v. 12, p. 699 (July 31, 1903). (Relates to West Ham Corporation electric lighting plant.)

Wisconsin.

*ADJUSTMENT OF ELECTRIC LIGHTING RATE. *Power*, v. 35, p. 498 (April 9, 1912). (Extracts from the reports of the Wisconsin Railway Commission regarding the influence of various fixed charges upon the rates.)

METHODS OF OBTAINING COST OF ELECTRIC LIGHTING SERVICE TO CONsumers Based on Decisions of the Wisconsin Railroad Commission. *Engineering and Contracting*, v. 37, p. 48 (Jan. 10, 1912). (Four pages.)

*UNIFORM CLASSIFICATION OF ACCOUNTS FOR ELECTRIC UTILITIES PREscribed by the Railroad Commission of Wisconsin, Dec., 1908. Edition 3. Madison, Wis., 1912. (Treats of tangible and intangible property, reserve accounts, etc.)

WISCONSIN CLASSIFICATION OF ELECTRIC ACCOUNTS. *Electrical World*, v. 53, p. 503 (Feb. 25, 1909). (Classification prepared by the Wisconsin Railroad Commission.)

Worcester, Mass.

THE APPRAISAL OF STREET LIGHTING SERVICE. *Engineering Record*, v. 66, p. 104 (July 27, 1912). (Decision by the Massachusetts Gas and Electric Light Commission in the Worcester street lighting case.)

York, England.

DEPRECIATION IN ELECTRIC LIGHTING. (Editorial.) *Municipal Journal* (London), v. 12, p. 12 (Jan. 2, 1903). (Policy of York Corporation; very brief)

RAILROADS—GENERAL.

ACCOUNTING DEPRECIATION. *Railroad Age Gazette*, v. 45, p. 415 (July 3, 1908). (On the relation of valuation to depreciation; one column.)

AMERICAN TRANSPORTATION QUESTION, p. 81; by Samuel O. Dunn. D. Appleton & Co., New York, 1912. (On the theory of railroad valuation; forty-two pages.)

AN AMERICAN TRANSPORTATION SYSTEM, p. 316; by George A. Rankin. G. P. Putnam's Sons, New York, 1909. (Contains a discussion of the appraisement of railroads; seventeen pages.)

APPORTIONMENT BETWEEN STATE AND INTERSTATE TRAFFIC OF RAIL-way Property Devoted to the Public Service; by Thomas D. O'Brien. *Proceedings,* Annual Convention of the National Association of Railway Commissioners, 1909, p. 306. (Method of valuation by reproduction cost; three pages.)

APPRAISED VALUE OF THE RAILWAYS IN FIVE STATES AND THE PROBABLE Cost of Reproducing All Railways in America. *Engineering-Contracting*, v. 34, p. 89 (Aug. 3, 1910). (Results and comparisons of State valuations.)

THE ARBITRARY DEPRECIATION CHARGE; by F. A. Delano. *Railroad Gazette*, v. 44, p. 681 (May 15, 1908). (A paragraph from the *Wall Street Journal*.)

ASSIGNMENT OF STEAM AND ELECTRIC LOCOMOTIVES, PASSENGER AND Freight Train Cars and Work Equipment Cost to the Several States and to Operating Divisions Within States. *Engineering and Contracting*, v. 39, p. 724 (June 25, 1913). (Abstract of paper by A. I. T. Thompson read before the Mississippi Valley States Conference.)

THE ASSIGNMENT OF VALUATION OF FACILITIES TO MORE THAN ONE STATE. *Engineering and Contracting*, v. 39, p. 726 (June 25, 1913). (A plan for apportioning value of general railroad shops between States; abstract of paper by Hugh H. Bryant read before the Mississippi Valley States Conference.)

BASIS OF VALUATION AS BETWEEN INTRASTATE AND INTERSTATE BUSINESS. *Railway Age Gazette*, v. 46, p. 319 (Feb. 12, 1909). (One paragraph.)

COMMERCIAL VALUATION OF RAILWAY OPERATING PROPERTY IN THE United States, 1904; by Henry C. Adams. U S. Bureau of the Census, Bulletin No. 21, Washington, 1905. (Reports by Prof. Henry C. Adams, Prof B. H. Meyer, William J. Meyers and others; eighty-eight pages.)

——Abstract. Railroads Valuations in State Reports. *Railroad Gazette*, v. 39, p. 226 (Sept. 8, 1905).

——Editorial. The Census Office Railroad Valuation. *Railroad Gazette*, v. 39, p. 194 (Sept. 1, 1905).

——Criticism on Bulletin No. 21 Issued by the Census Bureau, Assuming to Give the Commercial Value of Railroads; by E. Frederick Browne. Omaha, 1905.

A COMPARATIVE STATEMENT OF PHYSICAL VALUATION AND CAPITALIZA-tion; by the Bureau of Railway Economics. Washington, 1911. (Compares valuations made by States of Washington, South Dakota, Michigan and Minnesota.)

CONCERNING RAILWAY VALUATION. (Letter), by E. Gray, Jr. *Railway and Engineering Review*, v. 53, p. 105 (Feb. 1, 1913) (Criticism of paper by D. F. Jurgensen on Reproduction Costs.)

COST, CAPITALIZATION AND ESTIMATED VALUE OF AMERICAN RAILWAYS: An Analysis of Current Fallacies; by Slason Thompson. Edition 3. Bureau of Railway News, Chicago, 1908. (Aims to show that the value of railway properties in the United States exceeds their total net capitalization.)

——Editorial. Cost, Capitalization and Values of American Railways. *Railway Age*, v. 44, p 710 (Nov. 22, 1907)

THE CROSBY BILL ON RATE REGULATION. *Electric Railway Journal*, v. 40, p. 94 (July 20, 1912). (The author suggests a method of valuation of the properties of public service carriers, and outlines a suggested scale for a rate of return for new and old capital.)

DEDUCTIONS FOR OBSOLESCENSE JUSTIFIED. *Railway Age Gazette*, v. 49, p. 1093 (Dec. 2, 1910). (Decision of the Supreme Court of New York regarding the value of franchises and allowance for depreciation in taxation.)

DEPRECIATION; by S. M Hudson. *Railway Age*, v. 44, p. 175 (Aug. 9, 1907) (General discussion of depreciation; one and one-half pages.)

DEPRECIATION IN RAILWAY ACCOUNTING. *Railway Age*, v. 43, p. 728 (May 10, 1907). (Recommendations of Interstate Commerce Commission; one page.)

DEPRECIATION IN RAILWAY ACCOUNTING. *Railway Age*, v. 45, p. 623 (May 1 1908). (On equipment depreciation accounts; two pages.)

DEPRECIATION IN STEAM RAILWAY ACCOUNTING. *Electric Railway Journal*, v. 32, p. 748 (Oct. 3, 1908). (Memorandum compiled by Special Committee on Relations with Interstate Commerce Commission of the American Railway Association; one page.)

RAILROADS—GENERAL—(*Continued*).

DETERMINING A REASONABLE RATE. (Editorial.) *Railway World*, v. 56, p. 344 (April 19, 1912). (Comments on opinion of Judge Thomas G. Jones, of Alabama, on the cost of reproduction of a railroad, the basis for reasonable rates.)

DEVELOPMENT OF THE FREIGHT RATE HEARING REGARDING THE PHYSICAL Valuation of Railways. (Editorial.) *Engineering-Contracting*, v. 34, p. 263 (Sept. 28, 1910). (One and one-half columns.)

DISCUSSION OF REPORT OF COMMITTEE ON RATES AND RATE MAKING; by M. R. Maltbie. *Proceedings*. Annual Convention of the National Association of Railway Commissioners, 1910, pp. 200, 204. (On "market value," depreciation, and methods of making valuation; five pages.)

THE ECONOMICS OF RAILROAD CONSTRUCTION, p. 41; by Walter Loring Webb. John Wiley & Sons, New York, 1906. (Contains a chapter on the valuation of railway property.)

EQUIPMENT ACCOUNT FOR EACH CAR AND LOCOMOTIVE. *Railway Age Gazette*, v. 43, p. 640 (Nov. 29, 1907). (Method of keeping a depreciation account.)

ESTIMATING THE VALUE OF RAILROAD PROPERTY. *Railroad Gazette*, v. 37, p. 289 (Sept. 2, 1904). (On general principles of valuation; two columns.)

FAIR RETURN ON THE VALUE OF PROPERTY: A FALLACIOUS STANDARD. *Railway Age Gazette*, v. 48, p. 1129 (May 6, 1910). (From an address by Walker D. Hines before the Traffic Club of Pittsburgh.)

FEDERAL REGULATION OF RAILROAD SECURITIES AND VALUATION OF RAIL-road Properties; by Henry Fink. *Railway World*, v. 55, p. 390 (May 19, 1911). (Further extracts from statement to the Railway Securities Commission.)

GOVERNMENT SUPERVISION OF RAILWAY ACCOUNTS; by Henry C. Adams. *Electric Railway Review*, v. 19, p. 43 (Jan. 11, 1908). (Abstract of paper read before the Association of American Government Accountants.)

HEARINGS OF THE RAILROAD SECURITIES COMMISSION. (Editorial.) *Railway and Engineering Review*, v. 50, p. 1175 (Dec. 24, 1910). (Refers to question whether valuation of railroad should be used as a basis for issuing new securities.)

HENRY C. ADAMS ON RAILWAY VALUATION. *Railway World*, v. 51, p. 467 (June 7, 1907). (A brief analysis of the elements of valuation.)

HENRY FINK ON DANGER OF RAILWAY VALUATION. *Railway Age*, v. 43, p. 680 (April 26, 1907). (Declares there is no relation between valuation and rate regulation.)

INCOME ACCOUNT OF RAILWAYS. (Letter); by Frank May. *Railway Age*, v. 45, p. 560 (April 17, 1908). (How depreciation charges should be made.)

INITIAL COST, COST OF MAINTENANCE AND DEPRECIATION OF WOODEN Passenger Cars. *Engineering-Contracting*, v. 34, p. 215 (Sept. 7, 1910). (Rate of depreciation per year of different classes of cars.)

LET THE GOVERNMENT GO AHEAD AND PROSECUTE AND APPRAISE THE Railways. (Editorial.) *Railway Age Gazette*, v. 49, p. 566 (Sept. 30, 1910). (Relation between valuation and rates.)

MAINTENANCE CHARGES AND DIVIDENDS. (Editorial.) *Engineering Record*, v. 55, p. 86, (Jan. 26, 1907) (Alludes to comparison of repair costs in relation to traffic; one column.)

MAY RESERVE FUND TO RENEW ABSOLUTE EQUIPMENT. (Editorial.) *Electric Traction Weekly*, v. 6, p. 1473 (Dec. 3, 1910). (Decision by Supreme Court; article states that this is a new principle on valuation of special franchises.)

A METHOD OF APPRAISING NON-PHYSICAL RAILWAY VALUES. (Editorial.) *Engineering-Contracting*, v. 34, p. 517 (Dec. 14, 1910). (Comments on paper by Henry Earle Riggs on valuation of public utilities and on the method employed by Prof. Henry C. Adams in valuation of railroads.)

MR. HANSEL ON VALUATION OF RAILWAYS. (Editorials.) *Railway Age*, v. 44, pp. 71, 277 (July 19, Aug. 30, 1907). (On "State Valuation of Railways", by Charles Hansel in *North American Review* for July 5, 1907.)

——Letter. State Valuation of Railroads; by Carl Tombo. *Railway Age*, v. 44, p. 348 (Sept. 13, 1907).

——Letter. State Valuation of Railroads; by Charles Hansel. *Railway Age*, v. 44, p. 281 (Aug. 30, 1907).

NATIONAL VALUATION CONVENTION URGED, CONCERTED ACTION SHOULD BE Taken to Make Appraisal of Railways Economical, Intelligent and Just; by H. Bortin. *Railway Age Gazette*, v. 54, p. 836 (April 11, 1913).

THE NECESSITY OF DEPRECIATION RESERVES; by Henry L. Gray. *Railway Age Gazette*, v. 48, p. 1297 (May 27, 1910). (Two pages.)

RAILROADS—GENERAL—(*Continued*).

——Editorial. Depreciation Reserves. *Railway Age Gazette*, v. 48, p. 1290 (May 27, 1910).

——Letters. Depreciation Reserves. *Railway Age Gazette*, v. 49, p. 66 (July 8, 1910).

NOTES ON THE APPLICATION OF A DEPRECIATION CHARGE IN RAILWAY Accounting; by Frederic A. Delano. *Railway Age*, v. 45, p. 471 (March 27, 1908). (Depreciation of equipment, track, bridges, buildings, shop tools, etc., of the plant as a whole and limit of depreciation.)

OBSOLESCENCE AND DEPRECIATION FOR LOCOMOTIVES. (Editorial.) *Electric Railway Journal*, v. 41, p. 997 (June 7, 1913). (Comparison between steam and electric locomotives.)

PHYSICAL VALUATION AND CAPITALIZATION. *Railway Age Gazette*, v. 50, p. 121 (Jan. 20, 1911). (A statement of Prof. F. H. Dixon, which is said to refute a statement made by Clifford Thorne to the effect that railways in the States where valuations have been made are over-capitalized.)

PHYSICAL VALUATION AND CAPITALIZATION. *Railway World*, v. 55, p. 88 (Feb. 3, 1911). (Material prepared by the Bureau of Railway Economics; four pages.)

PHYSICAL VALUATION OF AMERICAN RAILWAYS. In Railway Library, 1910, p. 395; edited by Slason Thompson. Bureau of Railway News and Statistics, Chicago, 1911.

PHYSICAL VALUATION OF RAILROADS; by William J Wilgus. *Proceedings*, American Society of Civil Engineers, v. 39, p. 1109 (May, 1913) (Discusses basic principles, land values, inventorying and pricing measureable items, overhead cost, interest during construction, working capital and depreciation.)

——Abstract. Valuation of Steam Railroads. *Railway Age Gazette*, v 67, pp. 654, 692 (June 14, 21, 1913).

PHYSICAL VALUATION VERSUS RAILROAD RATES; by Henry Fink. *Railway World*, v. 55, p. 288 (April 14, 1911). (Extracts from statement made to the Railway Securities Commission.)

PHYSICAL VALUATIONS AND CAPITALIZATION OF RAILWAYS; by Slason Thompson. *Railway World*, v. 55, p. 1011 (Dec. 16, 1910). (Gives actual appraisals made in various States.)

——*Railway and Engineering Review*, v. 50, p. 1159 (Dec. 17, 1910).

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PROGRESS OF VALUATION OF RAILWAYS. *Railway Age*, v. 45, p. 103 (Jan. 24, 1908). (Considers the progress in methods of valuation, one page.)

PROPOSED VALUATION OF RAILROAD PROPERTY. (Editorial.) *Railway Age Gazette*, v. 42, p. 293 (March 8, 1907). (Concerning valuation as a basis for rate-making; one and one-half columns.)

RAILROAD ACCOUNTING AND THE HEPBURN LAW; by Arthur C. Graves. *Railroad Age Gazette*, v. 45, pp. 1543, 1597; v. 46, p. 18 (Dec. 11, 18, 1908; Jan. 1, 1909). (A protest against the requirements of the Government in railroad accounting.)

RAILROAD ACCOUNTING UNDER GOVERNMENT SUPERVISION; by M. P. Blauvelt. *Railway Age*, v. 45, p. 702 (May 15, 1908). (Discusses depreciation of equipment and replacement accounts.)

THE RAILROAD PROBLEM, RATES, UNIT COSTS AND EFFICIENCY; by F. Lincoln Hutchins. *Engineering Magazine*, v 42, pp. 488, 709 (Jan., Feb., 1912). (The paper contains the following divisions: rate-making, unit costs and efficiency, capitalization and regulation.)

RAILROAD TAXATION AND VALUATION; by C. F. Staples. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1909, p. 375 (Discusses gross earning and stock and bond methods of valuation; eight pages.)

RAILROAD VALUATION; by William J. Ripley. Ginn & Co., Boston, 1907 (Thirty-three pages.)

RAILROAD VALUATION, REPRODUCTION COST NEW AS A SOLE BASIS FOR Rates; by D. F. Jurgensen. *Journal*, Association of Engineering Societies, v. 49, p. 294 (Dec., 1912). (On method to be used in the valuation of railroads.)

RAILWAY ATTITUDE TOWARD VALUATION OF RAILWAYS. *Railway Age Gazette*, v. 49, p. 1137 (Dec. 16, 1910). (Arguments against a mere physical valuation; one page.)

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RAILWAY CAPITAL AND REAL VALUE; by Darius Miller. *Railway World*, v. 55, p. 28 (Jan. 13, 1911). (An article by the President of the Chicago, Burlington & Quincy R. R., in which he gives his views as to the relation between capitalization and rates.)

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——*Railway Age Gazette*, v. 48, p. 944 (April 8, 1910).

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——Abstract. *Electric Railway Journal*, v. 34, p. 1146 (Dec. 4, 1909).

RAILWAY VALUATION AGAIN. *Railway and Engineering Review*, v. 50, p. 1172 (Dec. 24, 1910). (Comments on statement of Judson C. Clements before the Railways Securities Commission; from *New York Sun*, Dec. 8, 1910.)

RAILWAY VALUATION BY THE CENSUS OFFICE. *Railway Age*, v. 37, p. 1103 (June 17, 1904). (On methods of valuation advocated by the Interstate Commerce Commission; one page.)

REPAIRS, RENEWALS, DETERIORATION AND DEPRECIATION OF WORKSHOP Plant and Machinery; by James Edward Darbishire. *Proceedings*, Institution of Mechanical Engineers, 1908, Pts. 3-4, pp. 812, 879. (The discussion of this paper includes remarks upon the depreciation of railway workshops and rolling stock.)

REPORT OF COMMITTEE ON LIFE OF RAILWAY PHYSICAL PROPERTY. *Proceedings*, American Electric Railway Accountants Association, 1912, p. 189. (Contains bibliography on life of physical property of railways and table of depreciation estimates.)

REPORT OF COMMITTEE ON RAILROAD TAXES AND PLANS FOR ASCERTAINING Fair Valuation of Railroad Property. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1903, p. 13; 1904, p. 50; 1905, p. 55; 1906, p. 33; 1908, p. 174; 1909, p. 321; 1910, p. 138; 1911, p. 61; 1912, p. 84. (Reports and discussions of varying length on taxation and the best methods of valuation.)

——Abstract of report for 1905. *Railway Age*, v. 40, p. 289 (Sept. 8, 1905).

——Abstract of report for 1910. *Electric Railway Journal*, v. 36, pp. 1062, 1192 (Nov. 26, Dec. 17, 1910); *Railway and Engineering Review*, v. 50, p. 1130 (Dec. 10, 1910.)

——Abstract of report for 1911. *Electric Railway Journal*, v. 38, p. 1026 (Nov. 11, 1911).

——Abstract of report for 1912. *Electric Railway Journal*, v. 40, p. 1065 (Nov. 23, 1912). (Treats of allowance for contingencies, interest during construction, basis for valuation, cost of reproduction new and original investment and fair value.)

——Editorials on report for 1912. Railway Valuation. *Electric Railway Journal*, v. 40, p. 1051 (Nov. 23, 1912); Valuation by the National and the State Governments. *Electric Railway Journal*, v. 40, p. 1139 (Dec. 7, 1912).

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——Abstract. *Electric Railway Journal*, v. 38, p. 812 (Oct. 13, 1911).

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——Editorial. The Usefulness of a Physical Valuation. *Railway Age Gazette*, v. 51, p. 1203 (Dec. 15, 1911).

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——Criticism. Mr. Loweth on Depreciation in Valuation. (Letter); by C. F. Loweth. *Railway Age Gazette*, v. 54, p. 1536 (June 20, 1913). (Criticism on editorial in issue of May 30th, 1913.)

——Editorial. Depreciation in Railway Valuation. *Railway Age Gazette*, v. 54, p. 1535 (June 20, 1913).

SOME NEGLECTED FACTORS OF FAIR VALUATION. (Editorial.) *Railway Age Gazette*, v. 46, p. 441 (March 5, 1909). (Concerning the relation between physical valuations as made by State Commissions and rate regulation.)

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STATISTICS AS TO THE LIFE OF STEEL RAILWAY BRIDGES. *Engineering-Contracting*, v. 30, p. 227 (Oct. 7, 1908). (Reference to depreciation of bridges and table showing life of ten railway bridges.)

AN UNSEEN FACTOR IN RAILWAY VALUATION. (Editorial.) *Railway Age Gazette*, v. 50, p. 821 (April 7, 1911). (In regard to the element which represents investment extinct and destroyed in the various railway re-organizations.)

USEFULNESS OF A PHYSICAL VALUATION. (Editorial.) *Railway Age Gazette*, v. 51, p. 1203 (Dec. 15, 1911). (Comments on the report and recommendations of the Hadley Securities Commission: one page.)

THE VALUATION OF AMERICAN RAILWAYS. (Editorial.) *Railway World*, v. 51, p. 410 (May 17, 1907). (Discusses value regarded as original or reproduction cost and as capitalization on the net earnings of the road.)

VALUATION OF PUBLIC SERVICE CORPORATIONS; by W. H. Williams. American Economic Association, New York, 1909 (Discusses the valuation of railroad taxes, rates, capitalization, etc.: fifty-one pages.)

——Abstract. *Electric Railway Journal*, v. 35, p. 76 (Jan. 8, 1910).

VALUATION OF RAILROAD PROPERTY; by Henry Fink. *Railway Age Gazette*, v. 45, pp. 587, 627 (July 24, 31, 1908). (Discusses physical valuation, capitalization and rate-making.)

VALUATION OF RAILROAD PROPERTY FOR LOCAL TAXATION. (Letter.) *Railroad Gazette*, v. 29, p. 863 (Dec. 10, 1897). (Decisions on valuation of railroads, based on opposing principles, cost of reproduction and earning capacity.)

VALUATION OF RAILROADS. (Editorial.) *Railway Age Gazette*, v. 42, p. 730 (May 31, 1910). (History of attempts to fix value of railroad properties, and statement that this cannot be done on a physical basis; one page.)

VALUATION OF RAILWAY PROPERTIES; by Robert Yates. *Railway Age Gazette*, v. 47, p. 975 (Nov. 19, 1909). (Considers a few of the principal elements of construction showing the cost value and depreciated value.)

VALUATION OF RAILWAYS. *Railway Age Gazette*, v. 46, pp. 173, 219, 261, 312 (Jan. 22, 29, Feb. 5, 12, 1909). (Full discussion of valuation in relation to State Railway Commissions, rates, etc.)

VALUATION OF THE RAILWAYS IN THE UNITED STATES; by B. H. Meyer. *Proceedings*, Annual Convention of the National Association of Railway Commissioners, 1904, p. 46. (General principles of valuation; four pages.)

——Abstract. Valuation of the Railways of the United States. *Railway Age*, v. 38, p. 729 (Nov. 18, 1904).

VALUE OF THE RAILROADS AND THEIR CAPITALIZATION; by H. T. Newcomb *Railroad Gazette*, v. 34, p. 671 (Aug. 29, 1902). (Argues that the capital stock of a railroad does not represent its real value; one page.)

VALUING RAILROAD PROPERTY; by Charles Hansel. *Traffic World*, v. 7, p. 735 (April 22, 1911). (Consideration of earning power, franchise and real value as elements of appraisal; address before the Southern Commercial Congress.)

WHAT IS THE VALUE OF A RAILROAD FOR PURPOSES OF TAXATION? by Charles Hansel. *Railroad Gazette*, v. 33, p. 271 (April 19, 1901). (On the work of Prof. M. E. Cooley, who was selected to examine the railroads in the State of Michigan, and on the subject of valuation in general; one page.)

United States Interstate Commerce Commission.

ACCOUNTING FOR DEPRECIATION OF EQUIPMENT. (Editorial.) *Railway Age*, v. 44, p. 36 (July 12, 1907). (Comments on the proposal to require railways to make formal depreciation accounts as outlined in Accounting Circular, No. 8, United States Interstate Commerce Commission.)

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CLASSIFICATION OF ACCOUNTS FOR INTERSTATE STEAM ROADS. *Electric Railway Journal*, v. 32, p. 348 (July 25, 1908). (New classifications as of July 1, 1908, supplements to the revised issues prescribed for the fiscal year beginning July 1st, 1907.)

CLASSIFICATION OF OPERATING EXPENSES AS PRESCRIBED BY THE INTERstate Commerce Commission. Third Revised Issue. Government Printing Office, Washington, 1911. (Gives annual per cent. allowed for depreciation.)

CLASSIFICATION OF OPERATING EXPENSES AS PRESCRIBED BY THE INTERstate Commerce Commission for Steam Roads. Third Revised Edition, Effective July 1st, 1908. Government Printing Office, Washington, 1908. (Contains condensed classification of account for small carriers and extended classification for large carriers.)

——Supplement. Government Printing Office, Washington, 1908.

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DEPRECIATION AND RENEWALS ACCOUNTS MODIFIED. (Editorial.) *Railway Age*, v. 44, p. 308 (Sept. 6, 1907). (Discussion of Circular 13, Accounting Series, United States Interstate Commerce Commission.)

DEPRECIATION IN RAILWAY ACCOUNTING. (Letter); by H. A. Dunn. *Railway Age*, v. 45, p. 756 (May 29, 1908). (Comments on methods of accounting recommended by the Interstate Commerce Commission.)

EVALUATION OF RAILROADS; by Walter S. McCormack. *Traffic World*, v. 8, p. 511 (Sept. 23, 1911). (States that carriers should be represented in work of the Interstate Commerce Commission.)

FORM OF GENERAL BALANCE SHEET STATEMENT AS PRESCRIBED BY THE Interstate Commerce Commission for Steam Roads. First Revised Issue, Effective June 15th, 1910. Government Printing Office, Washington, 1910.

HEARING ON DEPRECIATION OF EQUIPMENT ACCOUNTS BY INTERSTATE COMmerce Commission. *Electric Railway Journal*, v. 32, p. 236 (July 4, 1908). (Opinion of a Committee of the American Railway Association.)

——Editorial. Depreciation of Equipment Accounts. *Electric Railway Journal*, v. 32, p. 193 (July 4, 1908).

INTERSTATE COMMERCE COMMISSION DESIRE INFORMATION CONCERNING Treatment of Depreciation Accounts. *Railway Age*, v. 45, p. 221 (Feb. 14, 1908). (Questions which should be considered in keeping account of depreciation: abstract of Circular No. 7, Special Report Series.)

OBJECTIONS TO THE DEPRECIATION CHARGE. *Railroad Age Gazette*, v. 45, p. 1050 (Oct. 2, 1908). (A summary of views expressed by railroad officers on depreciation; memorandum of the American Railway Association's Special Committee to the Interstate Commerce Commission.)

——Depreciation in Steam Railway Accounting. *Electric Railway Journal*, v. 32, p. 748 (Oct. 3, 1908).

——Editorial. Proposed Valuation and Rates. *Railway Age*, v. 43, p. 268 (March 1, 1907).

PROTEST OF PENNSYLVANIA RAILROAD AGAINST CLASSIFICATION OF ADDItions and Betterments. *Electric Railway Journal*, v. 34, p. 908 (Oct. 23, 1909). (Formal protest to the Interstate Commerce Commission against required classification of accounts.)

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STATE VALUATION OF RAILWAYS; by Darius Miller. *Railway and Engineering Review*, v. 50, p. 1027 (Nov. 5, 1910). (Statements made at the rate hearing of the Interstate Commerce Commission.)

United States Railway Valuation Act.

THE BILL FOR PHYSICAL VALUATION. *Railway and Engineering Review*, v. 53, p. 169 (Feb. 22, 1913). (The text of the Railway Valuation Act.)

——Bill for Physical Valuation of Railways. *Railway Age Gazette*, v. 52, p. 811 (April 5, 1912). (Full text of the Adamson Bill for the physical valuation of railways by the Interstate Commerce Commission.)

CAN ENGINEERS BE TRUSTED TO ARBITRATE FAIRLY AND INTELLIGENTLY Between the Public Interests and the Property Interests? (Editorial.) *Engineering News*, v. 69, p. 1187 (June 5, 1913.) (On statement of Senator Robert M. La Follette that railroad valuation work should be placed in charge of an economist and not of an engineer.)

HEARING ON PROPOSED FEDERAL RAILROAD APPRAISAL. *Railway and Engineering Review*, v. 53, p. 140 (Feb. 15, 1913).

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PLAN FOR PHYSICAL VALUATION OF RAILWAY PROPERTIES. *Railway Age*, v. 43, p. 286 (March 1, 1907). (Abstract of a memorandum by H. C. Adams submitted to the President by the Interstate Commerce Commission.)

THE PLANK IN THE DEMOCRATIC PLATFORM PLEDGING THE APPRAISAL OF All Railways. (Editorial.) *Engineering and Contracting*, v. 38, p. 562 (Nov. 20, 1912). (Estimates the cost of a railway appraisal to range from $2.50 per mile, for very rough inventory, to $25 per mile for a very thorough appraisal, or about 50 cents per $1 000 of physical property appraised.)

PROPOSED NATIONAL VALUATION CONVENTION. (Letter); by L. C. Fritch. *Railway Age Gazette*, v. 54, p. 1536 (June 20, 1913). (Objections to holding convention.)

RAILROADS—GENERAL—(*Continued*).

——The Railway Valuation Act. *Engineering News*, v. 69, p. 482 (March 6, 1913). (Text of the law passed by Congress ordering the valuation of railroad properties.)

THE RAILWAY VALUATION ACT. (Letter); by Alex. C. Humphreys. *Engineering News*, v. 69, p. 688 (April 3, 1913). (The doubtful value of the provision of the law which requires the appraisers to analyze past financial transactions of railroads.)

STATE RAILWAY COMMISSIONERS AND FEDERAL VALUATION; by D. F. Jurgensen. *Railway and Engineering Review*, v. 53, p. 529 (June 7, 1913). (States that the Federal valuation is a contest between carriers and public, with the Interstate Commerce Commission as umpire.)

VALUATION OF THE RAILROADS. (Editorial.) *Engineering Record*, v. 67, p. 283 (March 15, 1913). (On the Railway Valuation Act.)

THE VALUE OF VALUATION. (Editorial.) *Electric Railroad Journal*, v. 41, p. 667 (April 12, 1913). (Doubt expressed as to the usefulness of the valuation of railroads provided for by Congress.)

RAILROADS—SPECIAL CASES.

Atchison, Topeka & Santa Fé R. R.

WHY RAILROADS NEED HIGHER RATES, p. 88; by E. P. Ripley. Chicago (?), 1910. (Takes up the physical value of the Santa Fé R. R. in testimony before the Interstate Commerce Commission, Chicago, 1910.)

Beaumont & Great Northern R. R.

VALUATION OF THE RAILWAYS OF TEXAS. *Engineering-Contracting*, v. 33, p. 370 (April 20, 1910). (Detailed value of the Beaumont & Great Northern R. R., with brief comments.)

Boston & Maine R. R.

*EVIDENCE AS TO THE VALUE OF NEW HAMPSHIRE ROADS EMBRACED IN the Boston & Maine System. In the Report of the Public Service Commission of New Hampshire on an Investigation of Railroad Rates, p. 300. Concord, N. H., 1912. (Discussion of formula for determining the value of railroad properties: Original cost; amount and market value of stocks and bonds; present as compared with original cost of construction; probable earning capacity.)

California.

*INSTRUCTIONS TO ASSISTANT ENGINEERS FOR INSPECTING RAILWAY PROPerty for Inventory and Appraisal, California Railroad Commission. *Engineering and Contracting*, v. 37, p. 619 (May 29, 1912).

Chicago, Milwaukee & St. Paul R. R.

*A. E. BUELL VS. CHICAGO, MILWAUKEE & ST. PAUL RAILWAY COMPANY; Submitted July 1, 1906, Decided Feb. 16, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 1, pp. 337, 478. Madison, Wis., 1908. (Discusses what constitutes a fair valuation of a railroad.)

ITEMIZED COST OF THE C., M. & ST. P. R. R. IN SOUTH DAKOTA. *Engineering-Contracting*, v. 28, p. 56 (July 24, 1907). (Estimates given in the Spokane rate case.)

Great Britain.

THE SERVICEABLE LIFE AND COST OF RENEWALS OF PERMANENT WAY OF British Railways; by R. Price-Williams. *Journal*, Iron and Steel Institute, v. 80, p. 183 (1909, Pt. 2). (Gives actual figures and diagrams of cost of maintenance on British railways for a number of years.)

Great Northern Ry.

ITEMIZED COST OF THE GREAT NORTHERN RAILWAY SYSTEM AS ESTIMATED by its Chief Engineer. *Engineering-Contracting*, v. 29, p. 271 (May 6, 1908). (Estimates given in testimony before the Interstate Commerce Commission in the Spokane rate case.)

ORIGINAL COST AND COST OF REPRODUCTION OF THE GREAT NORTHERN Railway (768 Miles) in the State of Washington. *Engineering-Contracting*, v. 32, p. 496 (Dec. 8, 1909). (Data as to the original cost, given by Halbert P. Gillette before the Railroad Commission.)

Kansas.

*KANSAS RAILWAY VALUATION, REPORT OF THE WORK OF THE ENGINEERing Department, Public Utilities Commission, from Date of Establishment to Nov., 1912; by C. C. Witt. *Public Service Regulation*, v. 2, p. 217 (May, 1913).

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Kansas City Southern Ry.

ACCOUNTING FOR ABANDONED PROPERTY. *Electric Railway Journal,* v. 39, p. 247 (Feb. 10, 1912). (Reply of Interstate Commerce Commission to the suit brought by the K. C. S. Ry., in regard to manner of accounting for value of property abandoned in the reconstruction of track.)

Louisiana.

***REPORT MADE BY THE STATE BOARD OF APPRAISERS SHOWING THE** Assessments Made of Property Employed in the Railway, Telegraph, Telephone, Sleeping Car, and Express Business for the Year 1899. (On the methods of valuation, and actual valuations made.)

Massachusetts.

THE FRANCHISE IN CAPITALIZATION. (Editorial.) *Railroad Gazette,* v. 37, p. 269 (Aug. 26, 1904). (Discussion of bill presented to Massachusetts Legislature allowing a new corporation to capitalize on a basis of market value of absorbed companies and to capitalize the franchises.)

Michigan.

EXPERT VALUATION OF RAILWAY AND OTHER CORPORATE PROPERTY IN Michigan. *Engineering News,* v. 44, p. 430 (Dec. 20, 1900). (Full account of the valuation made by the Michigan Board of State Tax Commissioners, describing organization for the work.)

RAILROAD TAXATION; by Robert H. Shields. In Sixth Report of the Board of State Tax Commissioners, Dec. 15, 1910, p. 53. Lansing, Mich., 1911. (Discusses several theories for valuation of railroads.)

RAILWAY CAPITAL AND VALUES; by W. H. Williams. *Railway Age Gazette,* v. 46, pp. 761, 805, 845, 903 (April 2, 9, 16, 23, 1909). (Outlines the methods used to obtain a physical valuation of railroad property in Michigan.)

——Abstract. *Railway and Engineering Review,* v. 48, p. 1047 (Dec. 26, 1908).

Minneapolis, St. Paul & Sault Ste. Marie Ry.

***IN RE INVESTIGATION ON MOTION OF THE COMMISSION OF PASSENGER** Rates Charged by the Minneapolis, St. Paul & Sault Ste. Marie Railway Company; Submitted April 9, 1907, Decided June 1, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 1, pp. 543, 581. Madison, Wis., 1908. (Contains brief reference to valuation of the road.)

Minnesota.

CURRENT RAILWAY PROBLEMS; by Samuel O. Dunn. Railway Age Gazette, New York, 1911. (Contains an article on valuation of railways with special reference to the physical valuation in Minnesota.)

***FORMS USED IN COMPILING INFORMATION IN THE 1906 APPRAISAL OF THE** Railways of Minnesota. *Engineering and Contracting,* v. 37, p. 52 (Jan. 10, 1912). (Four pages.)

JUDGE SANBORN ON STATE INTERFERENCE WITH INTERSTATE COMMERCE and Valuation of Railways. *Railway Age Gazette,* v. 50, p. 987 (April 28, 1911). (Opinions of the U. S. Circuit Judge in the Minnesota rate case; abstract of the discussion on the correct basis for the valuation of railways and a "fair return".)

THE MINNESOTA COMMISSION'S VALUATION FORMS. *Public Service Regulation,* v. 1, p. 301 (May, 1912). (Showing headings of some of the blanks used for detailed railway inventory and valuation in Minnesota, contributed by D. F. Jurgensen, Engineer.)

THE MINNESOTA RATE CASE; by Charles E. Otis. In Railway Library, 1910, p. 31; edited by Slason Thompson. Bureau of Railway News and Statistics, Chicago, 1911. (Contains analysis of valuation of property devoted to public service.)

THE MINNESOTA RATE CASES, OPINION OF THE SUPREME COURT OF THE United States. (63d Congress, 1st Sess., Senate Doc. No. 54). Washington, D. C., 1913. (Opinion of Justice Hughes of the Supreme Court on the valuation of railways.)

——Abstracts. Decision of the Supreme Court in the Minnesota Rate Cases. *Electric Railway Journal,* v. 41, p. 1064 (June 14, 1913); Railway Evaluation and Depreciation. *Engineering Record,* v. 67, p. 687 (June 21, 1913); The Supreme Court's Comments on Railway Valuation. *Railway Age Gazette,* v. 54, p. 1537 (June 20, 1913).

——Editorials. Construction Expenses in the Minnesota Rate Decision. *Electric Railway Journal,* v. 41, p. 1101 (June 21, 1913); *Railway Age Gazette,* v. 54, p. 1304 (June 13, 1913); The Minnesota Rate Decision. *Engineering Record,* v. 67, p. 679 (June 21, 1913); The United States Supreme Court on Principles of Railway Valuation. *Engineering News,* v. 69, p. 1338 (June 26, 1913).

RAILROADS—SPECIAL CASES—(*Continued*).

MINNESOTA RATE LAWS VOID. *Traffic World*, v. 7, p. 646 (April 15, 1911). (Statement is made that apportionment on the basis of revenue to the various classes of its business in order to determine the reasonableness of its rate, is the most reasonable and equitable method of assigning the value of a railroad property in a State, used for transportation; decision in case Shepard *vs.* Northern Pacific *et al.*, etc., United States Circuit Court.)

*TWENTY-THIRD ANNUAL REPORT OF THE RAILROAD AND WAREHOUSE Commission of Minnesota to the Governor for the Year Ending November 30, 1907, p. 14. St. Paul, 1908. (On method of making valuation; six pages.)

*——24th, 1908, p. 12. Minneapolis, 1909. (Contains report on valuation of the railways of the State.)

——Abstracts. An Analysis of the Appraisal of the Railways of Minnesota with Comments on the Same. *Engineering-Contracting*, v. 31, p. 172 (March 3, 1909); Valuation of Railways in Minnesota. *Railway Age Gazette*, v. 46, p. 225 (Jan. 29, 1909).

*——26th, 1910, p. 94. Minneapolis, 1911. (Contains findings and report on rate cases by Charles E. Otis, including valuations of property devoted to public service.)

——Abstract. *Railway and Engineering Review*, v. 49, p. 297 (March 13, 1909).

VALUATION OF RAILROAD PROPERTY IN MINNESOTA; by A. S. Cutler. *Year Book*, Engineers' Society, University of Minnesota, v. 16, p. 69 (1908). (Method of making valuation of railroad property in Minnesota; seven and one-half pages.)

VALUATION OF RAILWAYS IN MINNESOTA. *Railway Age Gazette*, v. 44, p. 877 (Dec. 20, 1907). (Describes methods of making valuation.)

VALUATION OF RAILWAYS IN MINNESOTA. *Railway Age Gazette*, v. 46, p. 269 (Feb. 5, 1909). (Describes the work of the Minnesota Railroad Commission.)

——Editorial. *Railway Age Gazette*, v. 46, p. 245 (Feb. 5, 1909).

Nebraska.

*FOURTH ANNUAL REPORT OF THE NEBRASKA STATE RAILWAY COMMISSION to the Governor, Year Ending November 30, 1911, p. 446. Omaha, 1911. (Includes statements of physical value of the various railroad and transportation facilities of the stock yards properties within the State of Nebraska, being the initial appraisal of July 1st, 1909.)

——State Railway Valuation: Nebraska Commission Reports Progress on State-Wide Appraisal of Physical Values. *Public Service Regulation*, v. 1, p. 445 (July, 1912).

ORGANIZATION FOR AND METHODS AND RESULTS OF PHYSICAL VALUATION in Nebraska; by E. C. Hurd. *Engineering and Contracting*, v. 36, p. 694 (Dec. 27, 1911). (Two pages.)

VALUATION OF RAILWAY PROPERTY—THE NEBRASKA METHOD. *Railway Age*, v. 37, p. 1219 (June 24, 1904). (Valuation for purposes of taxation; one page.)

New Jersey.

THE APPRAISAL OF THE RAILWAYS OF NEW JERSEY, AND PROGRESS IN Other States. *Engineering and Contracting*, v. 35, p. 701 (June 21, 1911). (One column.)

*PROGRESS REPORT OF THE BOARD TO RE-APPRAISE RAILROADS AND Canals in This State, March 9th, 1910. Trenton, N. J. (Gives organization, methods, and some data on actual values.)

RAILROAD APPRAISAL AND TAXATION IN NEW JERSEY; by Charles Hansel. *Engineering News*, v. 68, p. 334 (Aug. 22, 1912). (Defense of the method of appraisal of railroads for taxation in New Jersey.)

*REPORT ON REVALUATION OF RAILROADS AND CANALS, NEW JERSEY, 1911; by Charles Hansel. Trenton, 1912. (Treats of value of property, including the franchise, bonds and stocks, organization, operating cost, real estate, tangible personal property, depreciation, etc.)

THE VALUATION OF RAILROADS IN NEW JERSEY; by Charles Hansel. *Engineering Record*, v. 63, p. 594 (May 27, 1911). (Four pages.)

VALUATION OF RAILWAYS IN NEW JERSEY. *Railway Age Gazette*, v. 53, p. 243 (Aug. 9, 1912). (Methods adopted by Charles Hansel to ascertain value in accordance with State statute; results obtained by the work.)

New York, New Haven & Hartford R. R.

DEPRECIATION FUNDS OF THE NEW YORK, NEW HAVEN AND HARTFORD Railroad. (Editorial.) *Railway Age*, v. 43, p. 133 (Feb. 1, 1907). (One paragraph.)

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STREET AND INTERURBAN RAILROADS—GENERAL—(*Continued*).

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STREET AND INTERURBAN RAILROADS—GENERAL—(*Continued*).

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——*Electric Railway Journal*, v. 35, p. 284 (Feb. 12, 1910).

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VALUATION AND RATES. (Editorial.) *Street Railway Journal*, v. 30, p. 307 (Aug. 31, 1907). (On the similarity of street and steam railroad valuation; one and one-half columns.)

VALUATION OF A SHORT-TERM FRANCHISE. (Editorial.). *Electric Railway Review*, v. 17, p. 313 (March 9, 1907). (Should reconstruction and renewals be charged to capital accounts or provided for out of earnings, etc.)

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STREET AND INTERURBAN RAILROADS—GENERAL—(*Continued*).

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REVISED CLASSIFICATION OF ACCOUNTS FOR ELECTRIC RAILWAYS. *Electric Railway Review*, v. 19, p. 624 (May 23, 1908). (Classification of the Inter-State Commerce Commission, effective as of Oct. 1, 1908.)

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INSURANCE FUND AND DEPRECIATION RESERVES. (Letter); by John Blair MacAfee. *Street Railway Review*, v. 15, p. 292 (May 15, 1905). (Plans of the Augusta-Aiken Ry. & Electric Co. for taking care of depreciation.)

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HEARING ON ELECTRIC RAILWAY MAIL PAY. *Electric Railway Journal*, v. 41, p. 291 (Feb. 15, 1913). (Details of estimated cost of operation of present type of mail car on Boston Elevated Ry.; car, power, track investment, etc.; includes per cent. allowed for depreciation in each case.)

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ALLOWANCE FOR OBSOLESCENCE UPHELD IN FRANCHISE TAX CASE. *Electric Railway Journal*, v. 36, p. 1154 (Dec. 10, 1910). (Decision of New York Supreme Court in favor of Brooklyn Rapid Transit Co.; one-half page.)

APPROXIMATE VALUE PLACED ON PHYSICAL PROPERTY OF BROOKLYN Transit System. *Electric Railway Journal*, v. 34, p. 1261; v. 35, pp. 156, 248 (Dec. 25, 1909; Jan. 22, Feb. 5, 1910). (Testimony of B. J. Arnold and T. S. Williams before New York Public Service Commission.)

HEARING ON VALUATION OF CONEY ISLAND AND BROOKLYN R. R. *Electric Railway Journal*, v. 34, pp. 377, 398, 437, 469, 878, 1108, 1148, 1188, 1263; v. 35, pp. 104, 460 (Sept. 4, 11, 18, 25, Oct. 16, Nov. 27, Dec. 4, 11, 25, 1909; Jan. 15, March 12, 1910). (Hearing before the New York Public Service Commission, First District.)

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***RE MacREYNOLDS V. BROOKLYN UNION ELEVATED RAILROAD COMPANY** (Case 353). Reports and Decisions of the Public Service Commission, First District of the State of New York, v. 2, p. 246. New York, 1912. (Relation of fares and the valuation of Brooklyn Union Elevated R. R. Co.)

***RE MONHEIMER V. CONEY ISLAND & BROOKLYN RAILROAD COMPANY** (Case 350). Reports and Decisions of the Public Service Commisison, First District of the State of New York, v. 1 p. 705. New York, 1912. (Valuation of the Coney Island & Brooklyn R. R. Co. in relation to fares.)

*——A Ten-cent Fare to Coney Island Upheld by Public Service Commission *Electric Railway Journal*, v. 35, p. 456 (March 12, 1912). (Decision of Commission after considering the testimony as to the value of the Brooklyn Rapid Transit Co.)

THEORY OF STREET RAILWAY RATE REGULATION AS DEVELOPED IN THE Coney Island Fare Case; by Frank R. Ford. *Proceedings*, American Street and Interurban Railway Association, v. 29, p. 159 (1910). (On valuation; twelve pages.)

——*Electric Railway Journal*, v. 36, pp. 712, 752 (Oct. 12, 1910).

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Buffalo, N. Y.

DEPRECIATION CHARGES OF THE INTERNATIONAL TRACTION COMPANY. (Editorial.) *Electric Railway Review*, v. 19, p. 472 (April 18, 1908). (The definite policy of the International Traction Co. of Buffalo, in accounting currently for depreciation.)

FURTHER TESTIMONY IN BUFFALO REORGANIZATION CASE; by F. A. Sager. *Electric Railway Journal*, v. 39, p. 246 (Feb. 10, 1912). (Reviews methods followed in the inventory of the physical property of the International Traction Co.)

HEARING IN BUFFALO ON INTERNATIONAL TRACTION REORGANIZATION. *Electric Railway Journal*, v. 38, pp. 910, 991 (Oct. 21, Nov. 4, 1911). (An account of the methods used by B. J. Arnold in determining the cost to produce new the physical property of the International Traction Co. of Buffalo.)

——Editorial. Values Claimed by the Buffalo Plan. *Electric Railway Journal*, v. 38, p. 976 (Nov. 4, 1911).

California.

*ORDER OF CALIFORNIA COMMISSION REQUIRING VALUATIONS OF ELECTRIC Railways. *Electric Railway Journal*, v. 40, p. 1027 (Nov. 16, 1912).

Cardiff, Wales.

CARDIFF TRAMWAYS FINANCE. *Electrical Engineer*, v. 44, p. 879 (Dec. 24, 1909). (Discusses depreciation of electric railway at Cardiff.)

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TRACK DEPRECIATION AT CARDIFF; by John Allcock. *Tramway and Railway World*, v. 27, p. 30 (Jan. 6, 1910). (Brief statement.)

Chicago, Ill.

THE BASIS OF VALUATION IN THE CASE OF MUNICIPAL PURCHASE OF STREET Railways; by Sidney Ossoski. *Electric Railway Journal*, v. 36, p. 999 (Nov. 12, 1910). (Discusses methods of valuation using street railways of Chicago and Cleveland as examples; two pages.)

CHICAGO ELEVATED RAILWAY VALUATION. *Electric Railway Journal*, v. 39, p. 1087 (June 22, 1912). (Elements entering into the value of each piece of property in real estate valuation.)

——Abstracts. Reports of Appraisal of the Physical Properties of the Elevated Railways of Chicago. *Engineering and Contracting*, v. 37 (May 15, 1912); The Valuation of the Elevated Railroads of Chicago. *Engineering Record*, v. 65, p. 552 (May 18, 1912).

——Editorial. *Engineering Record*, v. 65, p. 534 (May 18, 1912). (Very brief.)

CHICAGO ELEVATED RAILWAYS, REPORT ON VALUATION OF PHYSICAL Property Including Real Estate and Rights of Way of the South Side Elevated Railroad Company, Metropolitan West Side Elevated Railway Company, Northwestern Elevated Railroad Company and Chicago & Oak Park Elevated Railroad Company, to the Local Transportation Committee of the City Council of Chicago, April 30, 1912, Reprinted May 9, 1912, with the Addition of the Final Figures of the Valuation Commission; by George F. Swain. Chicago, 1912.

CHICAGO ELEVATED RAILWAYS VALUATION. *Electric Railway Journal*, v. 39, p. 919 (June 1, 1912). (Analysis of right-of-way values.)

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DEPRECIATION AND CHICAGO VALUATION FIGURES. (Editorial Correspondence.) *Electric Traction Weekly*, v. 8, p. 584 (May 18, 1912).

DETAILED EXHIBITS OF THE TANGIBLE PROPERTY OF THE CHICAGO CITY Railway Company as of June 30, A. D., 1906, Accompanying the Valuation Report Submitted to the Committee on Local Transportation of the Chicago City Council; by Bion J. Arnold, Mortimer E. Cooley and A. B. du Pont. Chicago, 1906.

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

DETAILED EXHIBITS OF THE TANGIBLE PROPERTY OF THE STREET RAILWAY System in the Possession of and Operated by the Receivers of the Chicago Union Traction Company as of June 30, A. D., 1906, Accompanying the Valuation Report Submitted to the Committee on Local Transportation of the Chicago City Council; by Bion J. Arnold, Mortimer E. Cooley and A. B. du Pont. Chicago, 1906.

ELEMENTS OF VALUE IN A STREET RAILWAY. *Railroad Gazette*, v. 41, p. 567 (Dec. 28, 1906). (Valuation of the Chicago street railways by a commission prior to their purchase by the city; one page.)

ELEVATED VALUES IN CHICAGO. (Editorial.) *Electric Railway Journal*, v. 39, p. 817 (May 18, 1912).

ESTIMATED COST OF CABLE RAILWAYS IN CHICAGO. *Engineering and Contracting*, v. 37, p. 338 (March 20, 1912). (Cost of reproducing cable railway new as estimated by Bion J. Arnold.)

ITEMIZED UNIT COSTS OF 98 SPECIAL OVERHEAD LAYOUTS FOR A TROLLEY Railway. *Engineering-Contracting*, v. 34, p. 335 (Oct. 19, 1910). (Inventory made by the Traction Valuation Commission of Chicago.)

MAINTENANCE AND DEPRECIATION CHARGES OF THE CHICAGO UNION TRACtion Company. *Electric Railway Review*, v. 17, p. 247 (Feb. 23, 1907). (The policy of the City of Chicago, in allowing for depreciation in street railway property.)

——Editorial. Amount of Maintenance and Depreciation Charges. *Electric Railway Review*, v. 17, p. 244 (Feb. 23, 1907).

METHODS OF CONDUCTING THE VALUATION OF THE PHYSICAL PROPERTIES of the Chicago Consolidated Traction Co., with Summaries of Costs; by Philip J. Kealy. *Engineering-Contracting*, v. 34, pp. 274, 295 (Sept. 28, Oct. 5, 1910). (The valuation covers only that portion of the system within the city limits; describes methods and costs of track and power-house valuation and data of the electric power distribution.)

OPERATIONS OF THE COMPANIES UNDER THE 1907 ORDINANCES (CHICAGO). *Electric Railway Journal*, v. 40, p. 525 (Oct. 5, 1912). (Comparative values of street railways of Chicago, Commission's and Companies' estimates.)

RENEWALS AS DEFINED BY THE BOARD OF SUPERVISING ENGINEERS, CHIcago Traction. *Electric Railway Journal*, v. 37, p. 374 (March 4, 1911). (Classification of renewals of track, equipment, buildings and bridges.)

REPORT ON THE ENGINEERING AND OPERATING FEATURES OF THE CHICAGO Transportation Problem, Submitted to the Committee on Local Transportation of the Chicago City Council, p. 182; by Bion Joseph Arnold. Chicago, 1902. (Gives unit price estimates, valuation estimates, valuations under expiring grants, and cost of estimates; fifty-five pages.)

REPORT ON THE PHYSICAL PROPERTIES AND INTANGIBLE VALUES OF THE Calumet Electric Street Railway Company and the South Chicago City Railway Company as of February 1, A. D., 1908, Submitted to the Committee on Local Transportation of the Chicago City Council; by Bion J. Arnold. Chicago, 1908. 3 v. (General summary of value of physical property and detailed exhibits.)

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TWO REPORTS SUBMITTED TO COUNCIL COMMITTEE ON VALUES OF CHICAGO Elevated Railways. *Electric Railway Journal*, v. 39, p. 797 (May 11, 1912). (Comparison of reports by George F. Swain and the one submitted by the Harbor and Subway Commission.)

UNIT PRICES USED IN THE FIRST APPRAISAL OF ELECTRIC RAILWAYS IN Chicago. *Engineering and Contracting*, v. 37, p. 393 (April 3, 1912). (Detailed estimate of cost of street railway property in Chicago.)

VALUATION OF THE PROPERTY OF THE CHICAGO CONSOLIDATED TRACTION Co.; by B. J. Arnold and George W. Weston. *Engineering News*, v. 64, p. 241 (Sept. 1, 1910). (Short paragraph.)

VALUATION OF TWO STREET RAILWAY POWER PLANTS. *Engineering-Contracting*, v. 34, p. 280 (Sept. 28, 1910). (Part of the property of the Chicago Consolidated Traction Co.; two pages.)

VALUATION REPORTS ON CHICAGO ELEVATED ROADS. (Editorial Correspondence.) *Electric Traction Weekly*, v. 8, p. 556 (May 11, 1912).

VALUATIONS OF CHICAGO ELEVATED RAILWAYS. *Electric Railway Journal*, v. 39, p. 829 (May 18, 1912). (Detail figures and summaries of the explanatory statements made in connection with the two valuations.)

VALUE OF PROPERTY OF THE CHICAGO CONSOLIDATED TRACTION COMpany. *Electric Railway Journal*, v. 36, pp. 309, 374, 1111 (Aug. 20, Sept. 3, Dec. 3, 1910). (Valuation made by Bion J. Arnold and George W. Weston.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Cleveland, Ohio.

ARBITRATION OF OPERATING EXPENSE CHARGES IN CLEVELAND. *Electric Railway Journal*, v. 41, p. 925 (May 24, 1913). (Includes brief reference to depreciation of the railway plant, and maintenance, renewal and depreciation fund.)

DECISION OF ARBITRATOR IN CLEVELAND CONTROVERSY. *Electric Railway Journal*, v. 34, p. 1237 (Dec. 25, 1909). (Findings of Judge Taylor in the Cleveland Street Railway valuation.)

DECISION OF BOARD OF ARBITRATION IN THE CLEVELAND CASE. *Electric Railway Journal*, v. 41, p. 1159 (June 28, 1913). (Text of the finding, including allowance for maintenance, renewal and depreciation.)

——Editorial. The Arbitrated Result in Cleveland. *Electric Railway Journal*, v. 41, p. 1134 (June 28, 1913).

DEPRECIATION IN CLEVELAND. *Street Railway Journal*, v. 29, p. 743 (April 27, 1907). (On depreciation of track and cars; abstract from report of the Cleveland Electric Ry. Co.)

FINAL TESTIMONY AND ARGUMENTS IN THE CLEVELAND CASE. *Electric Railway Journal*, v. 41, p. 1070 (June 14, 1913). (Depreciation in the value of the property shown by tables submitted by Henry J. Davies.)

MAINTENANCE PROVISIONS OF CLEVELAND ORDINANCE; by H. J. Davies. *Electric Railway Journal*, v. 35, p. 614 (April 2, 1910). (Provisions for maintenance of physical property of Cleveland Ry. Co. determined in granting new franchise ordinance.)

OPERATION OF THE CLEVELAND STREET RAILWAY SYSTEM BY A NEW COMpany. *Electric Railway Journal*, v. 32, p. 433 (Aug. 8, 1908). (Provisions for maintenance and renewal fund in lease.)

TESTIMONY IN CLEVELAND VALUATION. *Electric Railway Journal*, v. 34, pp. 1024, 1068, 1159 (Nov. 13, 20, Dec. 4, 1909). (Opinions on valuation of the Cleveland Street Railway given by Frank R. Ford, Bion J. Arnold and others before Judge Taylor of the United States Circuit Court.)

VALUATION OF THE CLEVELAND ELECTRIC RAILWAY. *Electric Railway Review*, v. 19, p. 149 (Feb. 1, 1908). (Values of physical property, overhead charges, franchises, etc.; two pages.)

Detroit, Mich.

APPRAISAL OF THE CITY LINES OF THE DETROIT UNITED RAILWAY. *Electric Railway Journal*, v. 41, p. 897 (May 17, 1913). (Methods and summary of valuation.)

REPORT AND APPRAISAL OF THE DETROIT UNITED RAILWAY (CITY LINES), Detroit, Michigan, Oct. 1, 1909; by Frederick T. Barcroft. Detroit, 1910. (Contains brief data on method of making appraisal.)

——Abstract. The Appraisal Value of the Electric Street Railways of Detroit, Mich. *Engineering-Contracting*, v. 34, pp. 16, 35 (July 6, 13, 1910).

——Editorial. Noteworthy Article on Electric Street Railway Appraisal. *Engineering-Contracting*, v. 34, p. 1 (July 6, 1910).

REPORT OF THE COMMITTEE OF FIFTY. *Electric Railway Journal*, v. 36, pp. 111, 142 (July 16, 23, 1910). (Abstract of report of Committee to investigate Detroit Street Railway situation; contains brief references to the appraisal.)

REPORTS ON VALUATION OF DETROIT PROPERTY. *Electric Railway Journal*, v. 34, p. 1077 (Nov. 20, 1909). (Brief comparison of the valuations made by F. T. Barcroft and R. B. Rifenberick.)

RESULTS OF DETROIT INVESTIGATION. *Electric Railway Journal*, v. 34, p. 1276 (Dec. 25, 1909). (Concerning reports received by the Committee of Fifty on the street railway valuation.)

A STATEMENT OF "FACTS" CONCERNING THE SO-CALLED "BARCROFT Appraisal" of the Detroit United Railway Lines in the City of Detroit; by R. B. Rifenberick. Detroit, Mich., 1910. (A criticism of Mr. Barcroft's methods.)

THE VALUATION OF THE DETROIT STREET RAILWAYS. *Engineering News*, v. 64, p. 212 (Aug. 25, 1910). (An explanation of the situation with comparison of valuations made for the City with those for the Company; two pages.)

VALUATION OF THE TRACK OF THE DETROIT STREET RAILWAY SYSTEM. *Engineering News*, v. 64, p. 249 (Sept. 8, 1910). (Explains methods used in track valuation, including estimated value of twenty-one types of rail sections; one page.)

VALUATIONS OF THE DETROIT UNITED RAILWAY. *Electric Railway Journal*, v. 36, pp. 258, 294 (Aug. 13, 20, 1910). (Review of the facts, statement of the position of the Company regarding the Barcroft appraisal, brief abstract of the Barcroft appraisal, and a statement by R. B. Rifenberick.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Duluth, Minn.

DECISION OF WISCONSIN COMMISSION IN SUPERIOR CASES. *Electric Railway Journal*, v. 40, p. 1067 (Nov. 23, 1912). (Data on valuation of property of Duluth Street Ry. Co.)

Eastern Ry. & Light Co. See Fond du Lac, Wis.

Europe.

DEPRECIATION AS APPLICABLE TO ELECTRIC RAILWAYS; by Haselmann. *Electric Railway Journal*, v. 28, p. 1003 (Nov. 24, 1906). (Abstract of a paper read before the International Street and Interurban Railway Association giving methods of depreciation accounting in Europe; three pages.)

DEPRECIATION FUNDS IN EUROPE. *Electric Railway Journal*, v. 23, p. 696 (May 7, 1904). (Gives allowances made for depreciation.)

——Editorial. Depreciation. *Electric Railway Journal*, v. 23, p. 760 (May 21, 1904).

Fond du Lac, Wis.

***EXISTING FARES OF WISCONSIN ROAD UPHELD BY COMMISSION AFTER A** Valuation. *Electric Railway Journal*, v. 38, p. 193 (July 9, 1911). (Valuation of electric railway properties and division of valuation between city and interurban systems; decision of the Railroad Commission of Wisconsin in a fare case involving the Eastern Ry. & Light Co. of Fond du Lac.)

Fonda, Johnstown & Gloversville R. R.

LIFE OF RAILWAY PHYSICAL PROPERTY FROM THE ENGINEERING STANDpoint; by F. A. Bagg. *Electric Railway Journal*, v. 38, p. 1205 (Dec. 9, 1911). (Paper read before Street Railway Association of State of New York; discusses life of track and overhead lines and gives data regarding Fonda, Johnstown & Gloversville R. R.; one page.)

——Discussion. *Electric Railway Journal*, v. 38, p. 1210 (Dec. 9, 1911).

Glasgow, Scotland.

DEPRECIATION. (Editorial.) *Electrician*, v. 61, p. 744 (Aug. 28, 1908). (Practice of Glasgow Corporation Tramways.)

GLASGOW AND DEPRECIATION. *Municipal Journal* (London), v. 12, p. 795 (Sept. 4, 1903). (Very brief itemized statement of allowance for depreciation by Glasgow Corporation Tramways.)

GLASGOW TRAMWAYS. *Municipal Journal* (London), v. 14, p. 896 (Aug. 11, 1905). (Analysis of accounts of Glasgow Tramways, including allowance for depreciation.)

TREATMENT OF DEPRECIATION IN GLASGOW. *Electric Railway Journal*, v. 36, p. 362 (Sept. 3, 1910). (Discussion of the treatment of depreciation in accounts in report of the Glasgow Corporation Tramways.)

VALUATION OF GLASGOW TRAMWAYS. *Tramway and Railway World*, v. 27, p. 353 (May 5, 1910). (Decision in the appeal of the Glasgow Corporation Tramways against compulsory valuation.)

Great Britain.

B. E. T. DEPRECIATION. *Municipal Journal* (London), v. 16, p. 449 (May 24, 1907); v. 17, p. 459 (June 5, 1908). (Per cent. allowed for depreciation by sixteen British street railway companies.)

DEPRECIATION AND PERMANENT RENEWAL FUND; by William R. Bowker. *Street Railway Bulletin*, v. 6, p. 298 (May, 1907). (On the amount to be allowed for depreciation in street railroad property, giving cities of Manchester, Glasgow, Leeds, Bolton, and Wolverhampton, as examples.)

POLICY OF ENGLISH MUNICIPAL TRAMWAYS RESPECTING RENEWALS. *Electric Railway Journal*, v. 38, p. 661 (Oct. 7, 1911). (Two pages.)

RULES ON DEPRECIATION IN GREAT BRITAIN. *Electric Railway Journal*, v. 34, p. 476 (Sept. 25, 1909). (Allowances for depreciation in electric railway undertakings; one page.)

Illinois.

REPORT OF THE ILLINOIS TRACTION SYSTEM. (Editorial.) *Electric Railway Journal*, v. 36, p. 353 (Sept. 3, 1910). (Refers to annual allowance for depreciation.)

Kansas City, Mo.

DEPRECIATION CHARGES IN KANSAS CITY. (Editorial.) *Electric Railway Journal*, v. 36, p. 424 (Sept. 17, 1910). (On provision for depreciation made by the Kansas City Ry. & Light Co.; one paragraph.)

REPORT ON STREET RAILWAY SYSTEM OF KANSAS CITY. *Electric Railway Journal*, v. 41, p. 716 (April 19, 1913). (An investigation of the value of the property and its apportionment between the different municipalities

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

REPORT ON THE VALUE OF THE PROPERTIES OF THE METROPOLITAN STREET Railway System of Kansas City, v. 1; by Bion J. Arnold. Kansas City, Mo., 1913. (Report of Commission to investigate the capital value of the properties, various elements of such value, and how it shall be apportioned between the municipalities in a contract for a new franchise.)

A STREET-RAILWAY VALUATION. *Engineering News*, v. 69, p. 1053 (May 22, 1913). (Valuation of the street railway lines of Kansas City, Mo., by Bion J. Arnold; values found and various elements thereof and comparison with the values computed under four different methods.)

Kokomo, Marion & Western Traction Co.

DEPRECIATION ACCOUNT OF THE KOKOMO, MARION & WESTERN TRACTION Company. *Electric Railway Journal*, v. 38, p. 156 (July 22, 1911). (An arbitrary charge of a certain per cent. against each class or division of the property was adopted, to provide for current replacements and future requirements on account of losses due to age and wear; about the same percentages as are used by the Wisconsin Railroad Commission; one page.)

Lincoln, Nebr.

*TESTIMONY ON DEPRECIATION BEFORE NEBRASKA COMMISSION; by Edward W. Bemis. *Electric Railway Journal*, v. 35, p. 441 (March 12, 1910). (Testimony in relation to the consolidation of the properties comprising the Lincoln Traction Co.)

London, England.

LONDON TRAMWAY DEPRECIATION ALLOWANCE FOR INCOME TAX. *Electric Railway Journal*, v. 35, p. 274 (Feb. 12, 1910). (Very brief statement.)

Middlesex & Boston Street Ry.

LIABILITIES ON WHICH PROPER RETURNS SHOULD BE ALLOWED. *Electric Railway Journal*, v. 34, p. 464 (Sept. 25, 1909). (Hearing before Massachusetts Board of Railroad Commissioners; discussion of the basis on which the value of the property of the Middlesex & Boston Street Ry. should be computed.)

Milwaukee Electric Ry. & Light Co.

*DECISION IN THE MILWAUKEE FARE CASE. *Electric Railway Journal*, v. 40, p. 314 (Aug. 31, 1912). (Gives summary of physical valuation, going value, treatment of allowance for depreciation, rate of return, etc., of Milwaukee Light, Heat & Traction Co. and Milwaukee Electric Ry. & Light Co.)

DEPRECIATION AND RESERVE FUNDS IN MILWAUKEE. (Editorial.) *Street Railway Journal*, v. 26, p. 441 (Sept. 23, 1905). (Gives actual figures.)

DEPRECIATION OF PUBLIC UTILITIES PROPERTIES. *Electric Railway Journal*, v. 31, p. 169 (Feb. 1, 1908). (On the subject of depreciation in general, with reference to Milwaukee street railways.)

——Editorial. Depreciation. *Electric Railway Journal*, v. 31, p. 104 (Jan. 25, 1908).

DEPRECIATION RESERVES OF THE MILWAUKEE AND ST. LOUIS RAILWAYS. *Electric Railway Review*, v. 17, p. 319 (March 9, 1907). (Comparison of totals of maintenance and depreciation charges for fiscal year 1906, for street railways in Milwaukee, St. Louis, Chicago, and Glasgow.)

A DISCUSSION OF THE MILWAUKEE FARE DECISION. *Electric Railway Journal*, v. 41, p. 110 (Jan. 18, 1913). (Discusses valuation of Milwaukee street railway.)

THE ELECTRIC RAILWAY SYSTEM OF MILWAUKEE AND EASTERN WISCONSIN. *Street Railway Journal*, v. 15, p. 352 (June, 1899). (Provision of the Milwaukee Electric Ry. & Light Co., for depreciation and other reserves.)

——Editorial. *Street Railway Journal*, v. 15, p. 369 (June, 1899).

*HEARINGS ON MILWAUKEE FARE CASE BY WISCONSIN RAILROAD COMmission. *Electric Railway Journal*, v. 32, p. 395; v. 33, pp. 419, 464, 499, 554, 640, 683, 729, 766, 955 (Aug. 1, 1908; March 6, 13, 20, 27; April 3, 10, 17, 24; May 22, 1909). (Testimony by many experts on the value of the Milwaukee Electric Ry. & Light Co.'s property, allowances for depreciation, etc.)

——Editorial. *Electric Railway Journal*, v. 33, pp. 452, 536 (March 13, 27, 1909).

THE MILWAUKEE FOUR-CENT FARE DECISION. *Street Railway Journal*, v. 14, p. 397 (July, 1898). (Opinions of William H. Seaman, United States District Judge, in the case of the Milwaukee Electric Ry. & Light Co.; three pages.)

——Editorial. *Street Railway Journal*, v. 14, p. 381 (July, 1898).

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

*VALUATION BY EARNINGS; by Frank W. Stevens. *Public Service Regulation*, v. 1, p. 438 (July, 1912). (Opinion of Chairman, New York Public Service Commission, Second District, in the application of the Westchester Street R. R. Co. for authorization to issue capital stock.)

VALUE OF PROPERTY IN NEW YORK REORGANIZATION CASE. *Electric Railway Journal*, v. 41, p. 381 (March 1, 1913). (Decision of the New York Public Service Commission, Second District, in the case in which the Westchester Street R. R. asked authority to issue capital stock.)

Newcastle, England.

DEPRECIATION AND RESERVES, WARNING TO NEWCASTLE. *Tramway and Railway World*, v. 20, p. 258 (Sept. 6, 1906). (Discussion on the necessity of reserve and renewal funds; statistical.)

Niagara Gorge R. R.

TREATMENT OF DEPRECIATION ACCOUNTS OF NEW YORK PUBLIC SERVICE Commission. *Electric Railway Journal*, v. 34, p. 1073 (Nov. 20, 1909). (Rules adopted by the Niagara Gorge R. R.)

Philadelphia, Pa.

*PENNSYLVANIA STATE RAILROAD COMMISSION IN THE MATTER OF THE Complaints Against the Philadelphia Rapid Transit Company; Report to the Commission by Ford, Bacon & Davis, March 7, 1911. 2 v. New York, 1911. (Detailed report, comprising a series of tabulated statements, maps and diagrams on the physical valuation of the property of the Philadelphia Rapid Transit Co.)

Puget Sound Electric Ry.

*FIFTH ANNUAL REPORT OF THE RAILROAD COMMISSIONER OF WASHINGTON to the Governor Covering the Period from January 1 to November 1, 1910, p. 49. Olympia, Wash., 1910. (Refers to valuation of the Puget Sound Electric Ry.)

VALUATION OF THE PUGET SOUND ELECTRIC RAILWAY; by Henry L. Gray. *Engineering-Contracting*, v. 33, p. 482 (May 25, 1910). (Methods and details of valuation of physical property; four pages.)

St. Louis, Mo.

DEPRECIATION FUND IN ST. LOUIS. (Editorial.) *Electric Railway Journal*, v. 35, p. 433 (March 12, 1910). (One paragraph.)

LARGER DEPRECIATION FUND FOR ST. LOUIS. (Editorial.) *Electric Railway Journal*, v. 37, p. 247 (Feb. 11, 1907). (Comments on the policy of the United Railways Co. of St. Louis.)

*REPORT TO THE MUNICIPAL ASSEMBLY ON THE UNITED RAILWAYS COMpany of St. Louis by the St. Louis Public Service Commission; by James E. Allison. 2 v. Woodward & Tiernan Printing Co., St. Louis, 1912. (A statement of the principles which in the opinion of the Commission should be the basis of valuation and details of physical valuation of the property; Appendix A contains a discussion by James E. Allison, "Should Public Service Properties be Depreciated to Obtain Fair Value in Rate or Regulation Cases?")

——Abstracts. Report on United Railways of St. Louis. *Electric Railway Journal*, v. 41, p. 248 (Feb. 8, 1913); Finding Fair Value. *Public Service Regulation*, v. 1, p. 716 (Nov., 1912).

San Francisco, Cal.

FINAL REPORT ON SAN FRANCISCO. *Electric Railway Journal*, v. 41, p. 844 (May 10, 1913). (Analysis of value of street railways of San Francisco; report by Bion J. Arnold.)

Savannah, Ga.

DECISION OF COMMISSION UPHOLDING RATES OF FARE IN SAVANAH, GA. *Electric Railway Journal*, v. 39, p. 663 (April 20, 1912). (Relates to value of street railway property.)

Sheboygan, Wis.

*CITY OF SHEBOYGAN VS. SHEBOYGAN RAILWAY AND ELECTRIC COMPANY; Submitted Oct. 18, 1910. Decided Feb. 3, 1911. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 6, p. 358. Madison, Wis., 1912. (Contains table of valuation of the physical property of the Sheboygan Ry. & Electric Co.)

Spokane & Inland Empire R. R. System.

APPRAISAL OF THE SPOKANE AND INLAND EMPIRE ELECTRIC RAILROAD System; by Henry L. Gray. *Engineering and Contracting*, v. 36, p. 696 (Dec. 27, 1911). (Contains tables of cost of reproduction, depreciation, etc.; deals with methods adopted to determine the correctness of the allegation concerning the insufficiency of present rates.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

*RE METROPOLITAN STREET RAILWAY COMPANY REORGANIZATION (CASE 1305). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 113. New York, 1912. (Estimates of valuation of property.)

*RE 2ND REORGANIZATION PLAN OF 3RD AVE. R. R. CO. (CASE 1181). Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 2, p. 390. New York, 1912. (Report on valuation of the property of the Third Avenue R. R. Co.)

*REPORT OF A COMMITTEE OF THE BOARD OF ESTIMATE AND APPORTIONment and of the Public Service Commission for the First District with Relation to Pending Proposals for Rapid Transit Lines (1911). Proceedings, Public Service Commission for the First District, State of New York, v. 6, pp. 378, 399, 488 (June 27, 30, July 21, 1911). New York, 1912. (Estimated value of proposed New York Subway.)

*THE RETURN ON THE INVESTMENT IN THE SUBWAY OF THE INTERBOROUGH Rapid Transit Company of New York City, Submitted to the Public Service Commission for the First District of the State of New York, Report No. 7, Dec. 31, 1908; by Bion J. Arnold. New York, 1908. (Analysis of earnings and expenses, depreciation, etc.)

*SECOND CONDENSATION OF OPERATING ACCOUNTS FOR NEW YORK ROADS. *Electric Railway Journal*, v. 33, p. 67 (Jan. 9, 1909). (Classification of accounts made by New York Public Service Commission, First District; includes depreciation and treatment of appreciation.)

TENTATIVE CLASSIFICATION OF ACCOUNTS PREPARED BY NEW YORK PUBLIC Service Commission. *Electric Railway Journal*, v. 32, p. 349 (July 25, 1908). (The classification provides for two accounts to cover depreciation, one under maintenance of way and structures and one under maintenance of equipment.)

TREATMENT OF DEPRECIATION ACCOUNTS BY INTERBOROUGH RAPID TRANSIT Co. *Electric Railway Journal*, v. 38, p. 280 (Aug. 12, 1911). (One page.)

*TREATMENT OF DEPRECIATION AND MAINTENANCE IN GREATER NEW YORK. *Electric Railway Journal*, v. 39, p. 539 (April 6, 1912). (Table of rates of depreciation adopted by street and electric railway companies in accordance with the uniform system of accounts prescribed by the Public Service Commission of the First District.)

VALUATION OF STREET RAILWAY PROPERTIES. *Electric Railway Journal*, v. 33, p. 1122 (June 19, 1909). (Relates more particularly to the street railways of New York City; two and one-half pages.)

New York State.

*ACCOUNTS PRESCRIBED BY NEW YORK PUBLIC SERVICE COMMISSION, Second District. *Electric Railway Journal*, v. 32, p. 1373 (Nov. 14, 1908). (Provision is made for the treatment of depreciation in two primary operating expense accounts.)

BRIEF ON ACCOUNTING SCHEME SUBMITTED TO PUBLIC SERVICE COMMISSION, Second District, on Behalf of New York State Association. *Electric Railway Review*, v. 19, p. 591 (May 16, 1908). (Protest against requiring same methods of accounting for steam and electric railways and reasons for the protest).

INQUIRY BY PUBLIC SERVICE COMMISSION CONCERNING DEPRECIATION Accounts. *Electric Railway Journal*, v. 35, p. 793 (April 30, 1910). (Circular letter of inquiry issued to street railroad and electrical corporations, by the New York Public Service Commission, Second District; very brief.)

*JOINT HEARING ON UNIFORM ACCOUNTS FOR NEW YORK ELECTRIC ROADS. *Electric Railway Journal*, v. 32, p. 439 (Aug. 8, 1908). (Statement of H. J. Pierce, President of the International Ry. Co. of Buffalo, on depreciation, and of Howard Abel, Comptroller of the Brooklyn Rapid Transit System, on classification of accounts.)

RESOLUTIONS OF NEW YORK STATE ASSOCIATION CONCERNING TENTATIVE Classifications. *Electric Railway Review*, v. 19, p. 378 (March 28, 1908). (Relates to classification of the New York Public Service Commission, Second District.)

*SECOND CONDENSATION OF OPERATING EXPENSE ACCOUNTS FOR NEW YORK Roads. *Electric Railway Journal*, v. 33, p. 67 (Jan. 9, 1909). (Scheme of accounts prescribed by New York Public Service Commission, Second District, for street railroads; three paragraphs relating to depreciation.)

*STATE OF NEW YORK, SECOND ANNUAL REPORT OF THE PUBLIC SERVICE Commission, Second District, for the Year Ending Dec. 31, 1908; v. 2, Uniform System of Accounts. Albany, 1909. (Classification of accounts for street railroads, gas and electrical corporations; general amortization account including amount estimated for wear, tear and obsolescence of plant.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

VALUATION OF MILWAUKEE PROPERTIES. *Electric Railway Journal*, v. 38, p. 160 (July 22, 1911). (Details of the values placed on the property of the Milwaukee Electric Ry. & Light Co. by the Railroad Commission of Wisconsin; very brief.)

——Editorial. *Electric Railway Journal*, v. 38, p. 143 (July 22, 1911).

Milwaukee Northern Ry. Co.

***EDWARD J. CHROMASTER VS. MILWAUKEE NORTHERN RAILWAY COMPANY;** Submitted May 15, 1911, Decided March 12, 1912. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 8, p. 734. Madison, Wis., 1912. (Table of total valuation of property of Milwaukee Northern Ry. Co. and apportionment between city and interurban.)

Nebraska.

***PROPOSED DEPRECIATION ACCOUNT IN NEBRASKA.** *Electric Railway Journal*, v. 37, p. 919 (May 27, 1911). (Brief reference to hearing before the State Railway Commission on proposed depreciation account for electric railways.)

***RULE FOR TREATMENT OF DEPRECIATION IN NEBRASKA.** *Electric Railway Journal*, v. 38, p. 990 (Nov. 4, 1911). (Rules adopted by State Railway Commission to govern charges by electric railways, for maintenance, additions and betterments; one-half page.)

New Jersey.

REQUEST FOR LOWER FARES DENIED BY NEW JERSEY COMMISSION. *Electric Railway Journal*, v. 38, p. 1117 (Nov. 25, 1911). (Contains brief reference to the value of street railway property and allowance for maintenance and depreciation.)

STANDARD CLASSIFICATION OF STREET RAILWAY ACCOUNTS IN NEW JERSEY. *Electric Railway Review*, v. 37, p. 273 (Feb. 11, 1911). (The adoption, with two slight changes, of the standards of the American Electric Railway Accountants Association in regard to depreciation.)

New York City.

ANOTHER THIRD AVENUE CHAPTER. (Editorial.) *Electric Railway Journal*, v. 39, p. 230 (Feb. 10, 1912). (The Commission provides a plan for the retirement of excessive capitalization of the property; very brief.)

***APPRAISAL OF THE NEW YORK SURFACE SYSTEMS.** (Editorial.) *Electric Railway Journal*, v. 32, p. 111 (June 20, 1908). (Discussion of the proposed appraisal by the Public Service Commission; one page.)

THE APPRAISAL OF THE THIRD AVENUE STREET RAILROAD SYSTEM, NEW York City. *Engineering and Contracting*, v. 35, p. 666 (June 7, 1911). (Data relating to the appraisal taken from a pamphlet entitled "Opinion Disapproving Plan of Reorganization," July 29, 1910.)

AN ARBITRARY DEPRECIATION REQUIREMENT. (Editorial.) *Railway World*, v. 56, p. 141 (Feb. 16, 1912). (On decision of the New York Public Service Commission on the Third Avenue Ry.)

***LIFE OF ELEMENTS OF SUBWAY PROPERTY.** *Electric Railway Journal*, v. 39, p. 575 (April 6, 1912). (Estimates of E. G. Connette, Transportation Engineer, New York Public Service Commission, First District.)

METROPOLITAN STREET RAILWAY REORGANIZATION. *Electric Railway Journal*, v. 37, pp. 708, 756, 798, 876, 916, 976; v. 38, p. 240 (April 22, 29, May 6, 20, 27, June 3, Aug. 5, 1911). (Hearing before the New York Public Service Commission, First District; testimony in relation to the value of the property.)

***OPINIONS OF COMMISSION IN THIRD AVENUE CASE.** *Electric Railway Journal*, v. 39, p. 237 (Feb. 10, 1912). (Opinions on mortgages and accounting, amortization of discounts and depreciation of the Third Avenue R. R. property.)

PHYSICAL APPRAISAL OF THIRD AVENUE RAILROAD. *Electric Railway Journal*, v. 35, p. 228 (Feb. 5, 1910). (Estimate by Henry Floy of the value of the Third Avenue R. R.; one-half page.)

PLAN FOR REORGANIZATION OF THIRD AVENUE ROAD DISAPPROVED BY Commission. *Electric Railway Journal*, v. 36, p. 262 (Aug. 13, 1910). (Contains statement regarding the value of the property; three pages.)

***RE AMORTIZATION ACCOUNTS OF THE THIRD AVENUE RAILWAY COMPANY (Case 1181).** Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 51. New York, 1912. (Amortization of discounts and depreciation.)

***RE BOND ISSUE OF NEW YORK & NORTH SHORE TRACTION COMPANY (CASE 1398).** Reports of Decisions of the Public Service Commission, First District of the State of New York, v. 3, p. 63. New York, 1912. (Discussion of valuation of property of the New York & North Shore Traction Co.)

STREET AND INTERURBAN RAILROADS—SPECIAL CASES—(*Continued*).

Sunderland, England.

DEPRECIATION AT SUNDERLAND. *Tramway and Railway World*, v. 14, p. 478 (Nov. 12, 1903). (Estimated life and percentage set aside for depreciation of equipment and permanent way of street railway at Sunderland, England.)

Toledo, Ohio.

INVENTORY OF PHYSICAL RAILWAY PROPERTY OF TOLEDO COMPANY GIVEN to City. *Electric Railway Journal*, v. 36, p. 990 (Nov. 12, 1910). (Letter from Ford, Bacon & Davis; gives a list of the work and expense items entering into the construction cost which should be included in an appraisal; one page.)

Wausau, Wis.

*DECISION OF WISCONSIN COMMISSION: CONSIDERS THE RATE OF RETURN. *Electric Railway Journal*, v. 36, p. 404 (Sept. 10, 1910). (Statement in regard to the valuation of the Wausau Street R. R. Co.; one page.)

Wisconsin.

SOME PRINCIPLES ESTABLISHED BY THE WISCONSIN RAILROAD COMMISSION; by Edwin S. Mack. *Electric Railway Journal*, v. 37, p. 164 (Jan. 28, 1911). (Includes valuation; one page.)

*SYSTEM OF ACCOUNTS PRESCRIBED BY WISCONSIN RAILROAD COMMISSION. *Electric Railway Journal*, v. 33, p. 1076 (June 12, 1909). (Includes provision for a depreciation fund; two pages.)

*WISCONSIN CLASSIFICATION OF ACCOUNTS. *Electric Railway Journal*, v. 34, p. 366 (Sept. 4, 1909). (Gives slight changes from list published June 12, 1909, with extracts from introductory letter of the Commission.)

STREET AND INTERURBAN RAILROADS—UNVERIFIED REFERENCES.

ACCOUNTING OF DEPRECIATION BY ELECTRIC RAILWAYS; by Robert N. Wallis. *Journal of Accountancy*, May, 1907. (Discusses methods used and matters to be considered in electric railway accounting.)

ALLOWANCE FOR MAINTENANCE TO COVER DEPRECIATION. *Light Railway and Tramway Journal* (London), v. 21, p. 29 (July 2, 1909). (Details of allowances as agreed between Council of Institute of Municipal Treasurers and Accountants and the Inland Revenue Department for tramway and light railways as well as for municipal corporations.)

CLASSIFICATION OF ELECTRIC RAILWAY EXPENSES; by Willard Hubbard Lawton. *Journal of Accountancy*, v. 6, p. 114 (June, 1908).

COST OF CARRYING A PASSENGER; by C. L. S. Tingley. *Street Railway Bulletin*, v. 4, p. 793 (Nov. 15, 1905). (Abstract.)

DEPRECIATION AND RENEWAL FUNDS IN RELATION TO TRAMWAYS UNDERtakings; by G. W. Holford. *Light Railway and Tramway Journal* (London), v. 15, p. 294 (Oct. 5, 1906). (Abstract of paper read before the Municipal Tramways Association; contains table showing provision made for depreciation by street railways in sixty English cities.)

DEPRECIATION OF TRAMWAYS AND LIGHT RAILWAYS. *Light Railway and Tramway Journal* (London), v. 21, p. 80 (Aug. 6, 1909).

DEPRECIATION PROBLEM OF ELECTRIC STREET RAILWAYS; by W. B. Jackson. *Public Service*, Sept., 1911, p. 71.

LIFE OF DIFFERENT PARTS OF CAR EQUIPMENT, BEFORE AND AFTER USING Recording Wattmeters on Cars at Cape Town. *Journal*, Tramways and Light Railway Association, Sept., 1911, p. 241.

MANAGEMENT OF ELECTRIC TRAMWAYS; by Bowker.

PHYSICAL VALUE SCHEDULES OF THE CLEVELAND ELECTRIC RAILWAY CO. as of January 1, 1908.

REPORT OF THE STREET RAILWAY COMMISSION TO THE DETROIT COMMON Council on the Valuation of the Street Railways of Detroit. Journal of the Common Council, City of Detroit, 1899, p. 346.

REPORTING A STREET RAILWAY EXAMINATION (FROM THE CLIENT'S POINT of View); by W. B. Brockway. *Journal of Accountancy*, v. 4, p. 16 (May, 1907).

STREET RAILWAY COSTS; by M. E. Cooley. *Public Service*, v. 6, p. 117 (April, 1909).

STREET RAILWAY FARES IN LARGE CITIES; by Howard S. Knowlton. *Review of Reviews*, v. 32, p. 80 (July 1905).

STREET RAILWAY SETTLEMENT IN CLEVELAND; by E. W. Bemis. *Quarterly Journal of Economics*, Aug., 1908. (Thirty-three pages.)

STREET AND INTERURBAN RAILROADS--UNVERIFIED REFERENCES—(*Continued*).

TRAMWAY BOOKKEEPING ACCOUNTS; by D. McGall.

VALUATION OF CLEVELAND RAILWAY CO.: LETTER OF DEC. 17, 1909, TO CITY Council of Cleveland, Ohio, by R. W. Taylor, as Arbitrator Between City and Railways. (Copy in files, American Electric Railway Association.)

VALUATION OF PROPERTY OF RAILROADS IN THE DISTRICT OF COLUMBIA. 62d Cong., 2d Sess. Senate Doc. No. 335. (Letter in response to Senate resolution of Feb. 14th, 1912.)

TELEGRAPH AND TELEPHONE.

AN ANALYSIS OF COST OF TELEPHONE SERVICE. *Electrical World*, v. 55, p. 1243 (May 19, 1910). (One page.)

DEPRECIATION AND REPLACEMENT OF GROWING TELEPHONE PLANTS; by Burke Smith. *Journal*, Western Society of Engineers, v. 17, p. 779 (Oct., 1912). (Discusses renewal, life and depreciation of plant.)

——Abstract. Depreciation and Replacement of Telephone Equipment. *Electrical Review and Western Electrician*, v. 60, p. 790 (April 27, 1912). (Very brief.)

THE DEPRECIATION OF UNDERGROUND CABLES; by F. Fernie. *Electrical Review* (London), v. 60, p. 577 (April 5, 1907). (Method of computing depreciation of cables.)

DEPRECIATION OF UNDERGROUND CONDUITS, CABLES AND WIRES. *Electric Railway Journal*, v. 33, p. 881 (May 8, 1909). (Classification of property of the American Telephone & Telegraph Co.; very brief.)

DETERMINATION OF TELEPHONE RATES FOR LARGE EXCHANGES; by William H. Crumb. *Journal*, Western Society of Engineers, v. 12, p. 781 (Dec., 1907). (On depreciation, with a table giving per cent. to be allowed to depreciation account; one-half page.)

PLANT-INVENTORY AND VALUATION. *Electrical World*, v. 55, p. 295 (Feb. 3, 1910). (Abstract of paper by W. R. McGovern before the Wisconsin Electrical Association covering in a general way methods of taking inventories of telephone-exchange plants in Wisconsin.

——Abstract and Discussion. *Electric Railway Journal*, v. 35, p. 184 (Jan. 29, 1910).

TELEPHONE CONSTRUCTION METHODS AND COST. Chicago, 1908. (Contains cost data from the actual records of various telephone companies.)

***UNIFORM SYSTEM OF ACCOUNTS FOR TELEPHONE COMPANIES AS PRE**scribed by the Interstate Commerce Commission, pp. 16, 34, 53, 66, 71, 77. Washington, 1912. (Refers to treatment of depreciation.)

TELEGRAPH AND TELEPHONE—SPECIAL CASES.

Augusta, Wis.

***IN RE APPLICATION OF J. L. BALL FOR AUTHORITY TO INCREASE TELE**phone Rates; Submitted Sept. 10, 1907, Decided Nov. 25, 1907. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 105. Madison, Wis., 1909. (Brief reference to physical valuation.)

Boston, Mass.

REPORT TO THE MASSACHUSETTS HIGHWAY COMMISSION ON TELEPHONE Rates for Boston and Suburban District; by D. C. and William B. Jackson. Boston, 1910. (Diagrams, tables and maps; sixty-six pages.)

Chicago, Ill.

THE APPRAISAL OF THE CHICAGO TELEPHONE CO. AND A COMPARISON WITH the Results of Three Similar Appraisals. (Editorial.) *Engineering and Contracting*, v. 36, p. 269 (Sept. 13, 1911). (One column.)

APPRAISAL OF THE CHICAGO TELEPHONE COMPANY AND DETERMINATION of Fair Rates of Charge; by William J. Hagenah. *Engineering-Contracting*, v. 36, pp. 289, 445, 473 (Sept. 13, Oct. 25, Nov. 1, 1911). (Method of arriving at plant value, appraised value and income and operating expenses.)

REPORT ON THE TELEPHONE SITUATION IN THE CITY OF CHICAGO IN RESPECT to Service, Rates, Regulation of Rates, etc., Submitted to the Committee on Gas, Oil and Electric Light of the City Council of the City of Chicago; by a Special Committèe, composed of Dugald C. Jackson, William H. Crum, and George W. Wilder, April, 1907. Chicago, 1907. (The Committee states that it has endeavored to obtain data from Bell Telephone Companies of New York and elsewhere, but rates seem to have been dictated by estimates based on experience or the requirements of business expediency.)

TELEGRAPH AND TELEPHONE—SPECIAL CASES—(*Continued*).

Clinton Telephone Co.

*B. B. TIGHE ET AL. VS. CLINTON TELEPHONE COMPANY; Submitted Oct. 10, 1908, Decided Dec. 2, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 3, p. 117. Madison, Wis., 1910. (Refers to tentative valuation of physical property.)

Massachusetts.

SIXTEENTH ANNUAL REPORT OF THE MASSACHUSETTS HIGHWAY COMMISSION, for the Fiscal Year ending Nov. 30, 1908, p. 158. Boston, 1909. (Contains report by Dugald C. Jackson on the advisability of making an appraisal of the New England Telephone & Telegraph Co.)

——17th, p. 211. Boston, 1910. (Contains a summary report of the results of the inventory and appraisal of the New England Telephone & Telegraph Co., by D. C. and W. B. Jackson.)

TELEPHONE REPORT TO MASSACHUSETTS HIGHWAY COMMISSION. *Electrical World*, v. 55, p. 984 (April 21, 1910). (Brief reference to report on the New England Telephone & Telegraph Co., by D. C. and W. B. Jackson; states that this report on traffic and operating conditions, together with the appraisal which appeared previously, is the most detailed analysis ever made of telephone rates in an urban area of such scope.)

Michigan.

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Portage, Wis.

*IN RE APPLICATION OF THE PORTAGE TELEPHONE COMPANY FOR AUTHORITY to Increase Rates; Submitted May 19, 1908, Decided Aug. 27, 1908. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 2, p. 692. Madison, Wis., 1909. (Contains brief data on valuation.)

Seattle, Wash.

APPRAISAL OF THE PACIFIC TELEPHONE AND TELEGRAPH COMPANY OF Seattle; by Henry L. Gray. *Engineering and Contracting*, v. 36, p. 332 (Sept. 27, 1911). (Gives detailed estimate of cost of reproducing the plant; five pages.)

APPRAISAL OF THE SEATTLE TELEPHONE COMPANIES BY THE RAILROAD Commission of Washington; by Henry L. Gray. *Engineering and Contracting*, v. 35, p. 520 (May 3, 1911). (Describes the work and explains the causes which led to the appraisal.)

STUDY OF THE TELEPHONE SITUATION IN SEATTLE, WASH.: REPORT; by C. H. Judson and F. B. Hall. *Engineering News*, v. 65, p. 652 (June 1, 1911). (On depreciation and valuation; one column.)

Wisconsin Telephone Co.

*E. E. PAYNE ET AL. VS. WISCONSIN TELEPHONE COMPANY; Decided Aug. 3, 1909. In Opinions and Decisions of the Railroad Commission of the State of Wisconsin, v. 4, p. 1. Madison, Wis., 1910. (Intangible values embracing franchise, good will and going value are briefly discussed.)

TELEGRAPH AND TELEPHONE—UNVERIFIED REFERENCES.

DEPRECIATION AND REPLACEMENT OF GROWING TELEPHONE PLANTS; by Burke Smith. *Telephony*, April 27, 1912, p. 1062.

NATIONAL TELEPHONE CO., LIMITED, VS. HIS MAJESTY'S POSTMASTER-General. Great Britain Railway and Canal Commission Court. Judgment, Jan. 13, 1913, pp. 4209-39.

REPORT OF THE INVESTIGATION OF THE CHICAGO TELEPHONE COMPANY, 1911: by William J. Hagenah.

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TELEPHONE VALUATION, OKLAHOMA. Pioneer Telephone & Telegraph Co. vs. E. S. Westenhaver *et al.* and State of Oklahoma. Oklahoma Supreme Court, 1910, p. 1256.

THE ELIMINATION OF GRADE CROSSINGS

ON THE NEW YORK, CHICAGO & ST. LOUIS RAILROAD IN CLEVELAND, OHIO.

By A. J. Himes, Engineer of Grade Elimination.

PRELIMINARY DESCRIPTION.

The New York, Chicago & St. Louis Railroad, commonly called the "Nickel Plate," traverses the city of Cleveland, with its suburbs, from Rocky River on the west to Ivanhoe Road on the east, a distance of 16.94 miles.

Its course is intersected by 120 highways, twenty of which either did not cross at grade when the road was constructed in 1882, or had been separated from the grade of the railroad prior to 1909. In the latter year the work, which it is the purpose of this paper to describe, was undertaken.

Within the above limits, the road is crossed by seventeen double-track street car lines, only one of which is on private right-of-way. Eight of these lines were operated at the railroad grade in 1909. Within the same limits there were five steam railroad crossings, one of which, the Cleveland & Pittsburgh, was then and still is operated over a grade crossing. At that time the Nickel Plate operated two main tracks over 10.48 miles of the above distance, and the longest stretch of track without a grade crossing was that extending across the river valley and eastward. Its length was 3.39 miles.

The Lake Shore & Michigan Southern Railway, which, for several years, has been engaged in building third and fourth tracks from Buffalo to Chicago, crosses the Cuyahoga River in Cleveland on a single-track drawbridge. There is a very large amount of traffic on the river, and on that account the bridge is kept open for boats except during the actual passage of trains. Because of this very difficult operating condition which grows rapidly worse as traffic increases, and for other reasons, the Lake Shore & Michigan Southern Railway has acquired the Cleveland Short Line Railway, which was projected as a double-track belt line through the southerly portion of the city. In planning this road it was arranged to parallel the Nickel Plate for a distance of 2.4 miles and to occupy, with it, a common four-track roadbed. Because of the constantly increasing danger of accidents it was desired to avoid all grade crossings, and since the Nickel Plate needed a second track through this common territory, arrangements were made to build an entirely new roadbed and to eliminate the existing Nickel Plate grade crossings.

The ordinances providing for the construction of the above four-track roadbed and the elimination of grade crossings in Cleveland were

passed by the City Council about January 1, 1909. Half a mile of this four-track roadbed was to lie in the village of East Cleveland, and the ordinance for that portion was passed by the Council of the village of East Cleveland one year later.

Very strong opposition to these ordinances developed among residents of the territory where the road was to be built and particularly among the residents of East Cleveland. This opposition resulted in the final adoption of some very unusual bridge designs, which it was thought by interested persons would make the bridges at the various street crossings less unsightly than the usual steel construction.

The law under which the work was planned provided for the elimination of grade crossings when requested by the municipality, the expense thereof to be borne equally by the railroad and the municipality. In this instance, the crossings were not only to be eliminated, but additional tracks constructed and so the railroads agreed to bear the whole expense. For this purpose deposits were made with the city of Cleveland and the village of East Cleveland sufficient to cover their shares of the expense.

In Cleveland it was arranged that all street work and the highway bridges should be constructed by the city through the City Engineering Department in the usual manner. In East Cleveland all work was done by the railroad company.

Each ordinance required that the work covered therein be completed within two years from the date of its passage. The writer was asked whether that amount of time would be sufficient and he replied that, considering alone the construction work, the time would be ample, but the effect of possible delays not growing directly out of construction was indeterminate.

The ordinances mentioned provided for the elimination of all grade crossings between East Ninety-third Street, Cleveland, and Ivanhoe Road, East Cleveland, a distance of 4.97 miles. Of this distance the four-track roadbed covers 2.4 miles and a double-track roadbed was built the remaining distance.

Some of the larger items of work performed were as follows:

Excavation	691,000 cu. yds.
Embankment	537,000 cu. yds.
Concrete	63,000 cu. yds.
Steel Bridges	5,500 tons
Wooden Trestles, both temporary and permanent...	7,500 linear feet
Street Paving	2.18 miles
Sewers	2.76 miles
Water Pipes	2.24 miles

Fig. 1 shows the territory within which this work was to be done.

While there existed at the beginning only one main track, there were 10.7 miles of sidings and industrial spurs. The main line was

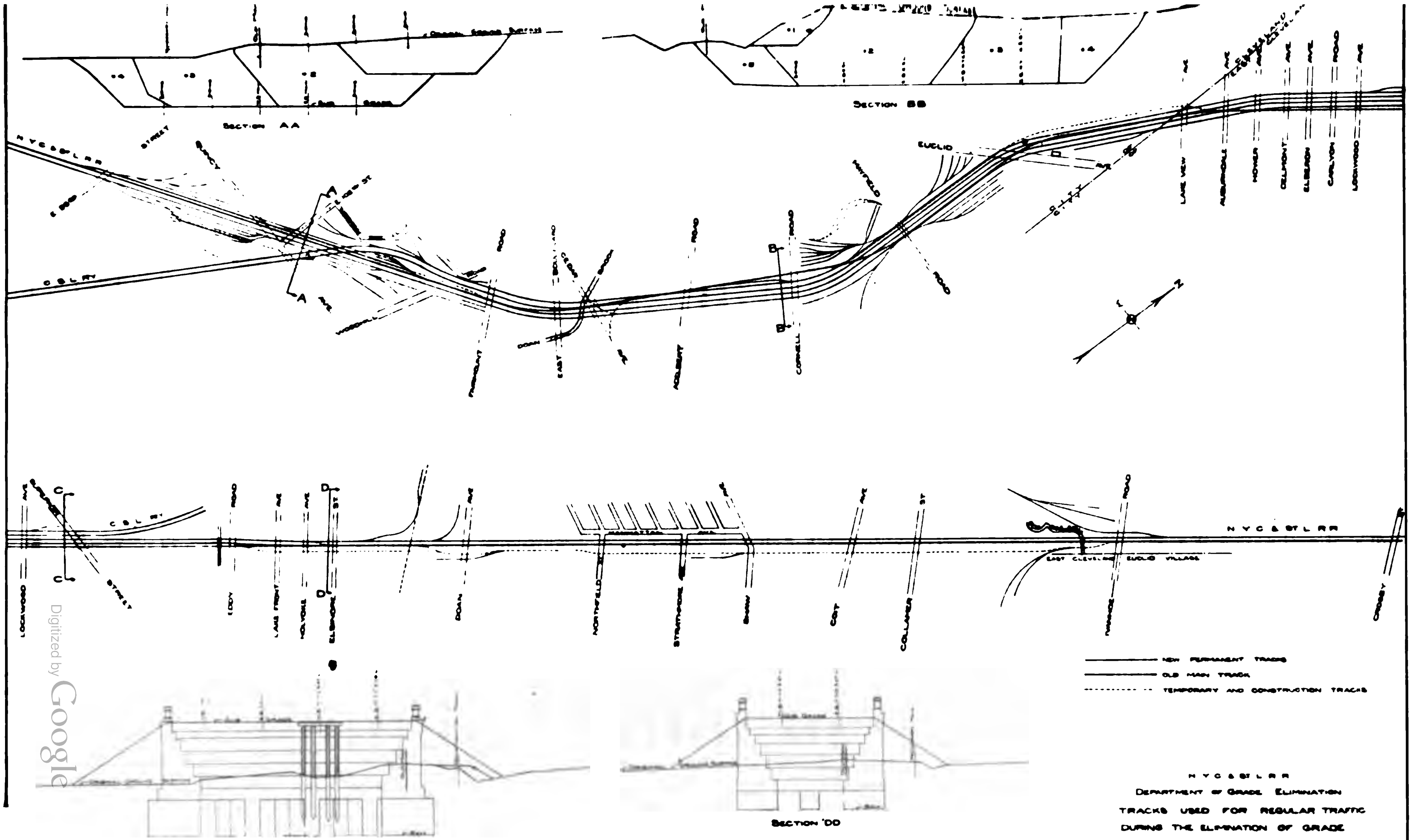


Fig. 1—Map Grade Elimination Territory.

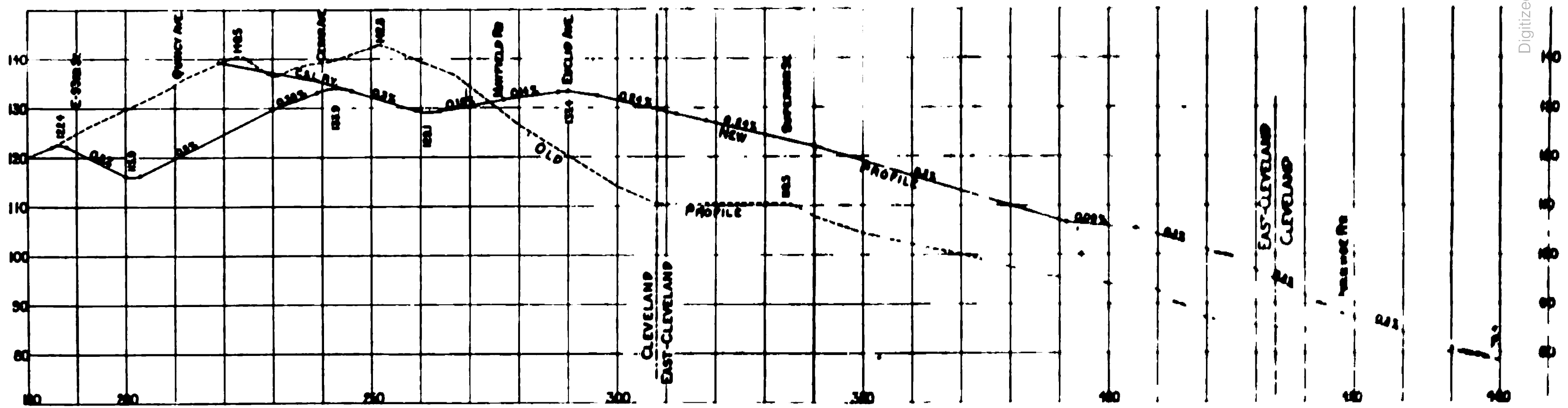


FIG. 2—PROFILE OF TRACKS—OLD AND NEW.

crossed at grade by three double-track street car lines and by two more such lines, not at grade, but which had to be depressed to agree with the new profile of the railroad.

There were four principal parties concerned in the performance of the work: Cleveland, East Cleveland, the Cleveland Short Line Railway and the Nickel Plate. The operation of the Nickel Plate trains within this territory would be seriously affected by the work of construction, and there was much street traffic to be cared for. These conditions made it advisable to segregate the work from all other affairs of the railroad and a separate department, known as the Department of Grade Elimination, was created for that purpose. The Department was given full control of all maintenance and construction within the territory described, and such control of the operation of trains as might be necessary in handling the work.

The Operating Department showed at all times an interested and willing spirit of co-operation that was much appreciated and the arrangement proved wholly satisfactory.

The Grade Elimination Department was also charged with all designs and estimates for the work and the necessary accounting. The Legal Department was charged with procuring the necessary real estate and the settlement of claims.

The steel bridge work was performed entirely by contract. It was completed about March 1, 1912. Two thousand one hundred cubic yards of concrete were built by contract with the railroad company during the summer of 1909. The bridges at Cornell and Adelbert roads were built by contract under the direction of the city. A few sewers and all street pavements in Cleveland were built by contract. All other work has been done by day labor. The working organization was recruited from the open market, with practically no assistance from the regular railroad organization.

It was realized in the beginning that to prepare plans and specifications for the whole of this work, in a manner that would permit of a definite contract, was practically impossible. The details of the work involved the co-operation of nearly every department of the Nickel Plate, several departments of the Lake Shore & Michigan Southern Railway and numerous departments of the city of Cleveland, of East Cleveland,* the public service corporations in each municipality, the property owners along the line and the various affected industries. Many of these parties could not be induced to study the subject and decide just what they would do until the time arrived to act. The handling of the Nickel Plate trains required an elasticity of control that could not be readily secured under a contract. By retaining full control of the construction work it could be adapted to the operations of other interested parties more readily than if it were placed in the hands of a contractor, and if necessary its completion might be hastened in ways that could not well be written into a contract. The conditions were such that under a contract it would have been practically impossible to escape numerous extra claims from

the contractor. Without a contract, it was possible to start construction work at once, thus avoiding the loss of time necessary for preparing contracts and specifications, receiving bids, entering into a contract and getting a contractor's plant on the ground.

On the other hand, the railroad had neither organization nor plant to handle the work.

It will be noticed on the profile (Fig. 2) that the excavation was entirely in Cleveland, while the embankment to be made was largely in East Cleveland. It has been stated that the East Cleveland ordinance was passed one year later than the Cleveland ordinance. It was not considered practicable to permit the Cleveland work to rest pending the discussion of the East Cleveland ordinance. It was of great importance that the whole Short Line project be completed at the earliest possible date.

In view of these conditions, it was decided to begin grading at once with a company force. A contract was let for about 10,000 cu. yds. of concrete masonry. Another contract was let for the steel railroad bridges in Cleveland, and the city let a few sewer contracts and contracts for two highway bridges.

At the end of the season the company's contractor had built about 2,100 cu. yds. of concrete and one highway bridge was nearly completed; 143,000 cu. yds. of excavation had been made. The progress had been exasperatingly slow.

After much consideration, the company's contract for concrete was canceled.

When the East Cleveland ordinance passed, the decision was made to handle all work possible with a company force, and it was forced ahead rapidly thereafter without regard to either season or weather.

Construction began March 1, 1909. The operation of the Cleveland Short Line Railway began July 1, 1912. The New York, Chicago & St. Louis Railroad was ready for double-track operation within the above territory October 1, 1912.

ORGANIZATION.

The original estimates and designs were prepared by the writer. When the preliminary negotiations were complete and instructions were given to proceed with the work, immediate steps were taken to develop the necessary organization. An office force was employed to handle the designing and estimating. Mr. A. C. Irwin, whose experience included the design of a part of the arches for the Florida East Coast Railway and an instructorship in bridge engineering at Cornell University, was placed in charge. The accounting was of such a nature as to require engineering experience, and it was placed under the supervision of Mr. L. V. Gaylord, of Branford, Conn. Mr. W. A. Miller, Professor of Railway Engineering of the University of the State of Missouri, was engaged to attend to the field engineering. For this purpose he secured a leave of absence from the University for one year, which, with two sum-

mer vacations, made his period of employment about eighteen months. At the expiration of that period he was succeeded by Mr. C. E. Drayer. Mr. J. W. Wilkinson, Division Engineer New York, Chicago & St. Louis Railroad, was in charge of the construction force.

There were employed three general foremen, one each for track work, concrete construction and timber bridges. The track foreman, Mr. Henry Willdis, had served the road for many years as District Supervisor of Track. Mr. John Kopp, bridge foreman, had long been an employe of the Erie Railroad and had worked on the New York, Chicago & St. Louis Railroad as contractor's foreman in the erection of bridges. The concrete foreman, Mr. John R. Bisset, is well-known in the East for his work on the New York canals, in the Hudson River quarries and on the railroads of New York and Pennsylvania.

An assistant yardmaster was employed to handle the traffic. Telephones were installed at intervals along the line and excepting a reduction of speed, the interference with regular trains was very slight.

The organization was not fully planned at the beginning of the work. It was in some respects an evolution, its various stages being the result of developments. Had the information on hand at the beginning of the work been sufficient to permit a proper organization, it could not have been formed at once because of the lack of men. Time was needed to secure the best assistants, and in some instances the organization was arranged to suit the men who were available, rather than wait for men having the exact experience needed. This is one reason why in the tables showing the actual organization and that now recommended the titles used are not those recommended. It was easier at first to call a man an Assistant Engineer and later to use him according to his fitness than to find in each case a man properly qualified for some particular position.

There should have been a Principal Assistant because in the rush of work many important matters could receive but scant attention from the Engineer of Grade Elimination and the interests of the company suffered accordingly.

It was originally intended that the field assistant engineer should report to the Division Engineer, but pressure of work and the experience of the men rendered the course pursued advisable.

The rate of pay for common labor at the beginning was $1.40 per day. In July, 1909, it was raised to $1.50 per day and in April, 1910, it was raised to $1.60. In July, 1912, it was again raised, the final rate being $1.70 per day.

Concrete laborers were paid in general 25 cents more per day than the rate for common laborers. Other workmen received various rates according to their experience and ability.

The labor employed was that found commonly about the city. With a single trifling exception, near the close of the work, no labor was brought from other points. At the beginning labor was very plentiful.

TABLE I—ORGANIZATION.

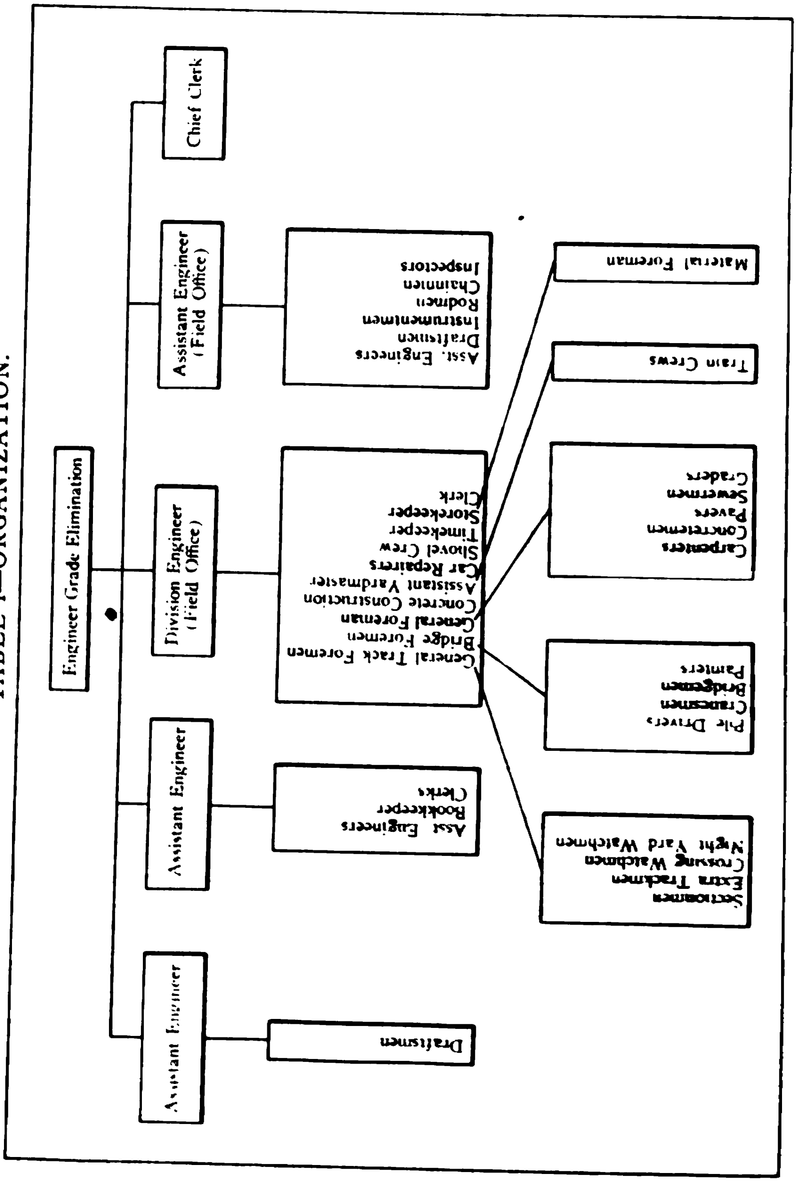
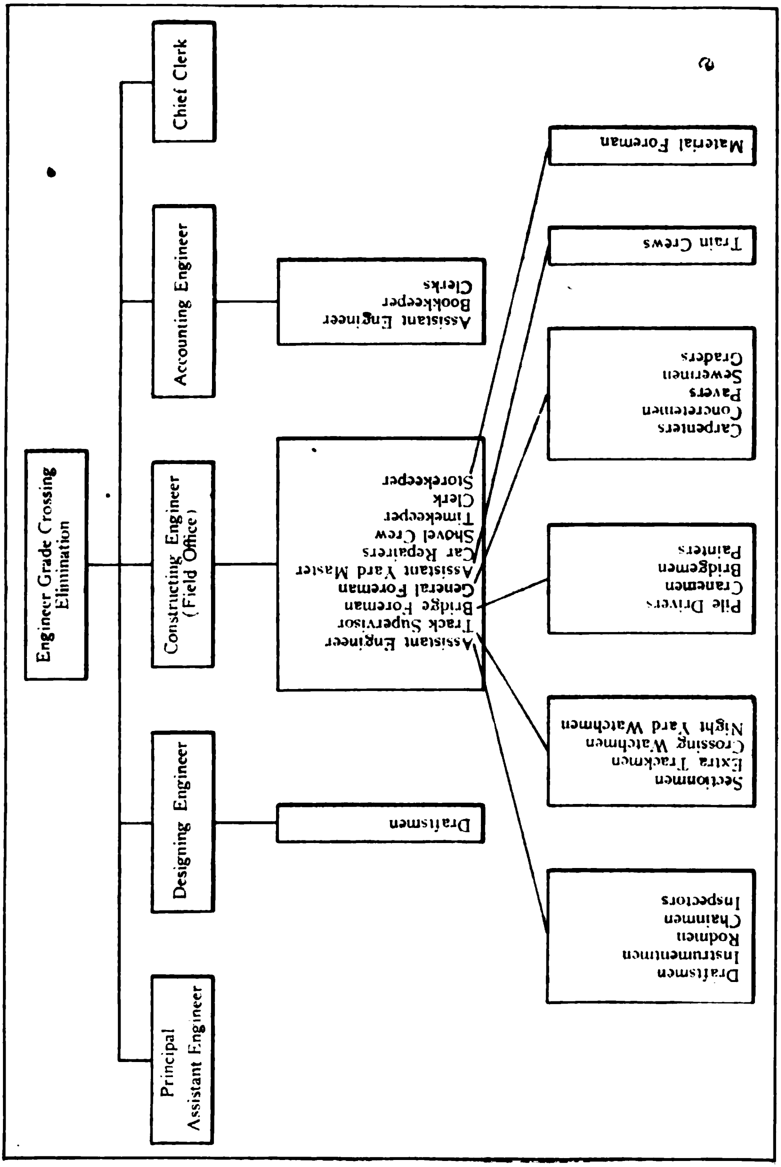


TABLE 2—ORGANIZATION NOW RECOMMENDED.



There had been much idleness during the preceding winter and men were eager to work. During the fall of 1912 there was an unusual amount of building in the city and the local contractors paid $2.00 for common labor. This condition resulted in bringing about seventy Greeks from Chicago during the latter part of the year.

The great bulk of the work was performed without a regular force of inspectors. The engineer corps kept an eye on the work while attending to its regular duties, and the writer spent much of his time on the ground.

Work performed through the agency of the city of Cleveland was inspected by city employes. In East Cleveland one or two inspectors employed by that city were always on the ground. All foremen were made to understand fully that only first-class work was desired, and after the first few weeks there was little disposition to sacrifice quality to either speed or lowness of cost.

The maximum force employed at any one time was about 700 men.

The selection of the employes was made with a great deal of care and now that the work is complete, it is recorded with satisfaction that no serious blunders were made and that an unusual degree of harmony and good-will prevailed throughout the work.

PLANT.

The construction equipment used on the work with cost, ownership, rentals and period of service is shown in Table 3. Only cars, locomotives and earth-handling machinery were supplied directly by the railroad. Tools, machinery, materials and supplies were obtained through the Purchasing Agent.

The time of service of each item of equipment was recorded under the proper account and the rental thus made up its share of the final expense.

The method used in establishing rental values for equipment purchased is illustrated by the case of Crane 8, as follows:

Cost of crane delivered and set up ready for service		$6,207.25
Depreciation for one month at 10 per cent. per year	$51.73	
Interest for one month at 6 per cent. per year	31.04	
Coal, oil and supplies for one month	28.60	
Watchman	60.00	
		$ 171.37

$171.37 expense and depreciation per month, equals $6.59 per day, divided by 26 working days per month, say $7.00 per day.

TABLE 3—PLANT

	Ownership	Cost	Length of Service	Rental	Remarks
Locomotives	N. Y. C. & St. L. R. R.		45 months	$3.40 per hour including engine and train crews	
Unloading Equipment: Lidgerwood unloader (60 ton full) Jordan Spreader Two Plows	N. Y. C. & St. L. R. R.	5971.56 3350. No Record	32 months	$10.00 per day	
Steam Shovel: 70 ton Bucyrus Shovel Two Tool Cars	Leased from L. S. & M. S. Ry.		29½ months	$11.00 per day	$10.00 for shovel. 50 cents each for cars.
Locomotive Crane No. 8	N. Y. C. & St. L. R. R.	6207.25	29 months	$7.00 per day	
Locomotive Crane No. 9	N. Y. C. & St. L. R. R.	6517.23	28¾ months	7.00 per day	
Loconotive Crane No. 10	N. Y. C. & St. L. R. R.	6475.			
Locomotive Crane fitted with leads for driving pile	N. Y. C & St. L. R. R.	206.51 6681.51	25½ months	7.00 per day	$206.51 does not include cost of hammer.
Concrete Mixer No. 1: No. 2½ Smith Mixer; 9 HP. O. & S. Vertical Engine, hoisting engine; 20 HP. boiler mounted on flat car and housed; 7-24 cu. ft. side discharge concrete cars; 29 chutes, 600 feet of track, etc., set up and ready for service	N. Y. C. & St. L. R. R.	3015.65	20½ months	$5.00 per day	Does not include cost or rental of car.
Concrete Mixer, No. 2: No. 24 Lakewood Mixer, batch hopper, engine, 20 HP. boiler, Byers hoisting engine, mounted on flat car and housed, 1 24-cu.ft. side discharge hopper car, 225 ft. of track, 25 chutes, etc., set up and ready for service		2314.50	17 months	$5.00 per day	Does not include cost or rental of car.
Concrete Mixer, No. 3	Leased		2½ months	$3.00 per day	
Pile Driver Bucyrus mounted on car.	N. Y. C. & St. L. R. R.		2¾ months	$10.00 per day	

TABLE 3—Continued

	Ownership	Cost	Length of Service	Rental	Remarks
Pile Driver....... Mounted on wooden rolls and skids.	Leased.......	....	3 months	\$4.00 per day	....
Trench Machine.......	Leased.......	....	5¾ months	\$167.50 per month	....
Steam Pump....... No. 4 Type A Hors. Cent. American Pump (6-in.) 10 HP. Vert. Boiler, 6-in. suction pipe and hose and fittings.	N. Y. C. & St. L. R. R.	511.06	18 months	\$2.60 per day	....
Compressed Air Plant....... *150 ft. air compressor, gasoline engine, tanks, 4 chippers, pipe, hose, bushing hammers and chisels 1 portable grinder, fittings. Mounted on flat car and housed.	N. Y. C. & St. L. R. R.	1650.00	16 months	\$1.50 per day	Does not include cost or rental of car.
Portable Saw Bench....... With 2 12-in. circular saws, gasoline engine and adjustable gauges.	N. Y. C. & St. L. R. R.	165.00	14 months	....	....
Apron Flat Cars.......	N. Y. C. & St. L. R. R.	....	39½ months	.45 per day	Including repairs.

*150 cu. ft. per minute.

GRADING.

The steam shovel was a 70-ton Bucyrus machine, not new, but in excellent condition. The shovel and crew were borrowed from the Lake Shore & Michigan Southern Railway. Mr. Willard Beahan, who has authority over the construction equipment of that road is entitled to credit for the able manner in which he maintained both shovel and crew in the highest condition of efficiency. No more skillful shovel engineer is to be found than the one supplied, and throughout the whole period of 29½ months no time was lost because of any absence or failure on the part of the crew. The shovel was put in the shop each winter for repairs and only 32 hours were lost through breakdowns while in service, an average of about one hour per month. Critics of efficiency in railroad management are invited to take notice.

Much of the material excavated was very hard shale. None of it was blasted except where excavated by hand. In some places it was so hard that teeth of manganese steel were used on the dipper and the progress was very slow.

Blasting was objectionable because of the proximity of dwellings and the frequency of damage claims.

The capacity of the shovel for hard digging is illustrated by Fig. 3, which shows the broken parts of a seven-foot six-inch circular sewer. This sewer was encountered while excavating for the depression of the tracks at East 105th Street, in the middle of the night.* Through some misinformation the sewer was supposed to be about six feet lower, and the shovel coming upon it unexpectedly, was obliged to break its way through or suspend work until the sewer could be removed in some other way. The volume of flow through the sewer was exceedingly small and there was no objection to breaking through. This the steam shovel did successfully in the night, although the sewer was constructed of a first-class quality of concrete reinforced by 1½ in. x ⅜ in. flat bars 15 in. center to center placed transversely of the sewer, and five ½ in. round bars in the top of the sewer and parallel with its length.

One of the difficulties encountered in the shovel work is illustrated by Fig. 4. When the shovel started east from Ninety-third Street it worked on a down grade as far as Quincy Avenue. The sewer in Quincy Avenue had already been depressed and afforded the only means of caring for drainage. It was hoped that the shovel would reach the sewer before any unusual runoff occurred, but the flood came when the shovel was still 274 ft. away, and it was necessary to dig a trench 274 ft. long and about 8 ft. deep to drain the cut.

A 2-yd. dipper was used throughout the major portion of the work.

A 3½-yd. dipper was used in the borrow pits where there was no hard shale.

*Night work was necessary while crossing the street to shorten the time of interference with street traffic.

FIG. 3—105TH STREET SEWER.

FIG. 4—FLOOD IN STEAM SHOVEL CUT.

The performance of the shovel varied from 550 cu. yds. to 2,300 cu. yds. per day; the larger quantity approaches its capacity. Below that the output was governed by the disposition of the material. Much of the material handled during the first season was wasted. Spoil banks were small and inconveniently located and the unit cost was high.

Because of the absence of spoil banks within easy team haul and the hardness of the material which could otherwise only be loosened by blasting, the steam shovel was used in excavating for the depression of Quincy Avenue, Cedar Avenue and Mayfield Road. This involved hauling the material in one case over a grade of 2½ per cent. on a 40-degree curve, and on 6 per cent. grades where the curvature was small. In one case the work trains were operated successfully over 40 to 50 ft. of 13 per cent. grade. Box cars invariably uncoupled in passing this grade, but there was no trouble with flat cars.

The locomotives operated on these grades and curves were of the 0-6-0 type with a wheel base of 11 ft.

The shovel worked uphill on grades of 6 per cent. This was especially difficult in hard material, but it was accomplished successfully.

The work in Mayfield Road was especially interesting because of the railroad crossing. The change of grade of the railroad at this point is slight, and in order to depress the street with a shovel the excavation beneath the easterly track was made by hand and a trestle built to carry the track. The cut was extended east of the track far enough to permit the shovel to be pulled clear of another track on the westerly side of the narrow right-of-way. The first running track was at the easterly side of the right-of-way. The shovel approached from the west. After excavating up to the trestle another trestle was partly built under the westerly track, the first trestle torn out, the shovel pulled across the first running track, the westerly trestle completed and traffic turned over the westerly track. The traffic was suspended about two hours to make this change, and the shovel was idle seven hours. (Fig. 5.)

The cost of excavation in Mayfield Road was 58 cents per cu. yd. There were 14,000 cu. yds. of material, mostly shale. The cost includes all track work, but none of the trestle work.

All excavated material was loaded on flat cars with hinged side boards. The average load per car was 11 cu. yds., excavation measurement.

The material was unloaded with plows and a Lidgerwood unloader and afterwards leveled with a Jordan spreader. (Figs. 6 and 7.) The embankments were generally made by jacking up the track as the filling progressed.

An embankment was built in this manner during the coldest months of the winter of 1910-11, an unusually severe winter. The average depth of fill was 13 ft. The total volume was 40,000 cu. yds. The material was mostly clay and generally moist. It would freeze very hard in a few hours. The cost per cu. yd. of labor on the fill was 10 cents, making the total cost $4,000.00. A trestle for use in making the embank-

ment and built to carry standard railway equipment would have cost not less than $9.40 per foot, or a total of $19,552. Assuming that there was use for the stringers and ties after completion of the fill a credit of $3.25 per foot, or a total of $6,760 could have been allowed, making the net cost of the trestle $12,792. This is three times the actual cost of the labor on the fill.

But apart from these considerations, it was necessary to build the embankment as soon as authority was secured to enter upon the land and there was no time to build a trestle.

Four work trains were in service much of the time. Occasionally a fifth train was used. One locomotive was always needed to serve the shovel. In busy times one locomotive was used in spreading the unloaded material and two trains in hauling. One train was generally required to serve the concrete construction.

FIG. 5—STEAM SHOVEL IN MAYFIELD ROAD.

The grading was not all shovel work. Teams were used occasionally both with scrapers and wagons, considerable quantities of earth were handled by hand and more with the cranes. Teams cost 50 cents and 60 cents per hour. They were hard to find and unsteady in their work, and were, of course, used as little as possible.

The cranes were useful in foundation work and in depressing streets. In many cases material from the street was scraped or trucked on rails in skips to the overhead bridge and there hoisted by a crane and dumped behind the abutments. Spoil banks were very scarce, but, if plentiful, any earth deposited thereon would have been wasted while behind the abut-

FIG. 6—LIDGERWOOD UNLOADER.

FIG. 7—JORDAN SPREADER.

ments it was of value. The work of the crane as above was more expensive than a short wagon haul, but where wagons could not reach the embankments, the cranes did good service.

The average cost of prism excavation was 28 cents per cu. yd. This cost does not include any labor on the embankments, after the material was unloaded.

CONCRETE.

Three concrete mixers were used on the job. They were all mounted on cars. Two were equipped with hoisting engines for charging. The third was charged by wheelbarrows moving over the cars, and was used in building the floor slabs and other work where a large output was not required. The manner of operation is illustrated in Figs. 8 and 9. In Fig. 8, the housing was carried over the boiler and the incline proved too steep for economical wheeling. This is the first job undertaken. The method was at once abandoned for that of Fig. 9. At a later date wheeling was again resorted to, but the charging of the mixer was done at a lower elevation and with better results.

Between Lakeview Road and Superior Street, a distance of 2,600 ft., the streets—eight of them—were so close together and the available right-of-way was so narrow that it was thought best to make use of a temporary trestle. The new location of the tracks was such that about two-thirds of the street abutments could be built without interference with traffic on the old line (Fig. 1). It was impossible to get traffic on the upper level and close only two adjacent streets at a time—a provision of the ordinance—without using a trestle. This condition being recognized and the trestle decided upon it was thought best to mix the concrete on the trestle and pour it by chutes into the abutment forms below. If this reason were not sufficient, a further one for so mounting the mixers was that because of the large number of structures and their small average volume much time could be saved in moving the plant. Furthermore, there was no room for derricks, stock piles and stationary plant.

The concrete for many footing courses and small concrete structures was mixed and placed by hand. This was partly because the small yardage made it economical, partly to hasten the work when the mixers were busy and in the case of the footings, when sheeting and bracing were used in the foundations, it was better to get the footings in, part or all of the bracing removed and the forms erected, before bringing the mixer on the work; otherwise it would stand idle a part of the time and thus reduce the volume of concrete placed per month below the rate necessary to keep up with the schedule.

The maximum output of one mixer per day of 20 hours was 200 cu. yds.

The average output of one mixer per month for 11 months was 1,345 cu. yds.

The drum of a new Smith one-half-yard mixer was worn out in mixing 20,752 cu. yds.

FIG. 8—SERVING MIXER WITH WHEELBARROWS.

FIG. 9—SERVING MIXER WITH CARS.

All structures were divided into sections in such a way as to preclude cracks from expansion and settlement, and each section was poured complete in one run; or at any rate, such was the intention and the failures were few. This required extra gangs and considerable night work. The men, as a rule, did not like to work at night, but they seemed to appreciate the necessity and to take an interest in the success of the work. The utmost harmony prevailed and it was very rare that a section once started, failed of completion through lack of men. It did happen occasionally that because of the failure of a work train to serve the mixer or because of a sudden storm, a section was left incomplete. In these cases no water has ever seeped through the masonry on the resulting seams, but the attempts at concealment in finishing the concrete were not wholly successful. The color of the patchwork, when used, to remedy defects along the seams, was not always the same as that of the original concrete.

The concrete was generally mixed quite wet. This was necessary in order to have it flow well in the chutes, and to insure a dense watertight product without tamping. It was aimed to draw the surplus water off from the concrete at the rear of the masonry and thus avoid a deposit of laitance on the face of the structure. In this respect the success was very good, but it might have been better.

The labor employed was wholly unskilled and it was very hard for the foremen to teach the men just what was required.

The concrete work was carried on continuously the year around. In freezing weather, the water and sand were heated and salt water (a saturated solution) was used when there was to be no steel in contact with the concrete. In but one instance was there any sign of a failure. This case was in a section of a retaining wall that was placed by hand. The final conclusion as to the cause was that salt had been thrown in the mortar without being first dissolved in water. Has anyone else had such an experience?

The concrete was generally mixed in the proportion 1:3:6. In bridge floors and reinforced work it was made 1:2:4.

Where the mixer car was obliged to stand upon the ground towers were frequently used for elevating the wet concrete to a point where it might be distributed by gravity. In some cases this method was very economical. At Euclid Avenue, after railroad traffic had been turned over the bridge, there was so much traffic above and below and so little available space that no other method seemed at all comparable in either economy or speed (Fig. 10).

Wooden chutes were made two feet wide and 8 in. to 10 in. deep. With planed boards the preferable slope is four in. per foot. Slopes of two in. per foot were used at times, but a man was then required to keep the chutes clear. A slope of six in. per foot will cause the ingredients to separate and requires the use of baffles to retard the motion.

Iron chutes were made 20 in. wide and eight in. deep. The maximum slope used was four in. per foot, the minimum slope two in. per foot.

The slope is, of course, dependent upon the amount of water in the concrete.

Great pains were taken to remove all form marks and other defects from the surfaces of the masonry. The cheapest method and one that proved generally pleasing was to bush-hammer the surfaces. Such work was done at a cost of 4 cents per sq. ft. Other surfaces were rubbed smooth with carborundum bricks at a cost varying from 4 cents to 10 cents per sq. ft. No concrete surface can be made to retain a good appearance unless all laitance be thoroughly removed. Its deposition on the surface may be prevented by proper care in filling the forms.

FIG. 10—CONCRETE CHUTE, EUCLID AVENUE BRIDGE.

Little difficulty was experienced in making repairs or correcting defects. Surfaces to be patched were carefully cleaned and then soaked with water. The mortar was applied in comparatively thin layers by throwing on forcibly with a trowel, each layer being permitted in turn to harden. Such work has gone through three winters without sign of failure.

Iron trowels were never used in finishing the surface. Very smooth surfaces were secured with carborundum. Rough, sandy surfaces, resembling Cleveland sandstone were secured by rubbing with wooden floats while the concrete was still green. This is an excellent finish and can be done at a cost less than bush-hammering if there are no surface defects to be removed.

When the aggregate was desired to show, the mortar was brushed away while green with wire brushes. A good finish of the latter sort requires the aggregate to be uniform in size and uniformly placed. It is not easy to secure.

A very beautiful surface may be secured by bush-hammering a concrete made with quartz gravel.

STEEL WORK.

The steel work of the railroad bridges was divided into three separate contracts, the first covering the bridges in Cleveland, the second covering the bridges in East Cleveland, from Lakeview to Superior Street, inclusive, and the third the East Cleveland bridges beyond Superior Street.

The division was made in this manner because when letting the contracts it was not possible to foresee when the bridges, not included, could be erected. For instance, a contract for the Cleveland bridges was made prior to the passage of the East Cleveland ordinance. It seemed unwise to contract for bridges in East Cleveland before the right was secured to erect them.

The bridges were all designed according to the New York Central Lines specifications of 1910. The Cleveland bridges were the first to be constructed under these specifications, and a large part of the writer's work, as member of the New York Central Lines Bridge Committee, was to secure the adoption of a joint specification in order that it might be available for these bridges.

The traffic of the Short Line promised to be as heavy as any in America, while that of the Nickel Plate is lighter. The Nickel Plate is operated wholly independent of the New York Central Lines, but its relations with the latter are so close that to build any portion of the four-track bridges for less than the maximum requirement seemed very short-sighted. Joint specifications seemed the easiest means of securing authority for proper bridges.

The live load in these specifications is Cooper's E-60, with an alternate loading of 144,000 lbs. equally distributed on two axles spaced seven feet center to center.

The unit stresses are tension 18,000 lbs. per sq. in.; compression 16,000 — 70 l/r, but not to exceed 15,000 lbs.; and the impact $I = S/L + 300$.

The use of unit stresses somewhat higher than common is in recognition of the apparent impossibility of any material increase of live load without a general reconstruction of all roadway structures.

The bridge floors are of I-beams encased in concrete or bearing a concrete slab above the beams.

Fifteen of the bridges were plate-girders; seven of them were three-hinged arches.

The former Nickel Plate East Boulevard bridge (Fig. 11) was considered a very handsome structure, and the people of East Cleveland in

the hope of beautifying their city demanded the construction of similar arch bridges. To this the Company objected strongly, but it was finally arranged to build such bridges on a few particular streets.

There was no material difference in weight between the plate-girder and arch bridges. There was a considerable difference, however, in the volume of masonry in the foundations. The rock surface was about 12 to 16 ft. below the surface of the streets and the foundations of the arch bridges were designed to carry the arch thrust to the rock. This increased the volume of concrete materially above what was needed for the plate-girder bridges.

No lateral bracing was used in any of the bridges, it being left for the floor slabs to furnish lateral rigidity. Before the construction of the

FIG. 11—OLD BOULEVARD BRIDGE.

floor slabs, temporary wooden stringers were laid on the I-beams to support the track to grade, and the trains caused considerable motion in the arch bridges and the girders having curb supports. In all such cases temporary wooden bracing was used to check the motion.

At Euclid Avenue a combination of long span, sharp skew, curve and heavy loading made it necessary to use curb supports. These were provided in the ordinance. Curb supports were likewise used at Mayfield Road.

A state law makes any ordinance providing for curb supports subject to a referendum vote. Besides the general uncertainty of the outcome of such a vote, it involves much delay and the company would have been glad to avoid the opportunity. At Euclid Avenue, however, there was

FIG. 12—OLD TRUSS SPAN AT CEDAR AVENUE.

FIG. 13—CORNELL ROAD BRIDGE.

strong objection to a truss for aesthetic reasons—so-called—and the curb supports were the only alternative.

Fig. 12 shows the old single-track truss span at Cedar Avenue and the Nickel Plate eastbound track over the new bridge. The picture was taken on the day when regular traffic was turned over the new bridge, March 24, 1910.

Fig. 13 shows the bridge at Cornell Road. It is typical of the highway bridges.

At Mayfield Road (Fig. 24) the curb supports were only a matter of economy, but the street was coupled with Euclid Avenue in a separate ordinance so that they could stand or fall together. At the end of the prescribed time, 60 days after the passage of the ordinance, no petition had been filed and no referendum was held.

The old bridges at Cedar Avenue and East Boulevard were dismantled, and all new bridges were erected with derrick cars. All bridge erection was done by contract.

The contracts for the railroad bridges were let and the bridges built without delay of any kind to the general progress.

The steel work of the highway bridges consisted mainly of lattice columns and longitudinal beams, and was wholly encased in concrete.

The division of tonnage between railroad and highway bridges was as follows:

Railroad bridges	4,870 tons
Highway bridges	630 tons
Total	5,500 tons

EAST BOULEVARD BRIDGE.

The original East Boulevard bridge was a three-hinged plate-girder arch with ornamental stone abutments. It was built for two tracks and had a clear span of 57 ft. 4 in. The floor consisted of I-beams with a deck plate to which the rails were fastened directly by clips and bolts. It was designed by C. F. Schweinfurth, Architect, and was regarded as typical of what a park bridge should be (Fig. 11).

The revised grade of the railroad contemplated a lowering of the Nickel Plate track over the boulevard 6.39 ft. The grades of the two roads separate just east of Cedar Avenue, the Nickel Plate descending sharply to the westward on a five-tenths grade, and the Short Line ascending westward on a three-tenths grade. The effect of this divergence at the boulevard is to produce a difference in the elevation of grade lines of 3.72 ft.

The city ordinance provided for a plate-girder bridge with concrete abutments, but when the time came to detail the work the park department entered a protest. It desired that the bridge be rebuilt on lines exactly similar to those of the former bridge. This it was impossible to do, a fact, which, after careful study, was reluctantly admitted. A stone arch was then proposed with abutments similar to those of the old

bridge. This was impracticable because of insufficient space from top of rail to soffit on the Nickel Plate side. The negotiations continued a whole year without results. It was finally proposed by Mr. Hoffman. Chief Engineer of the Board of Public Service, that a composite bridge be built, that a reinforced concrete arch be built for the Short Line tracks where there was plenty of room, and that a plate-girder be used for the Nickel Plate tracks. The present bridge is the outcome of that suggestion. It was designed to meet the requirement that it have something of the appearance of the old structure except that the arch should be concrete instead of steel. To carry out the idea as well as possible the writer offered to surround the plate-girder with a parapet and false soffit, so as to present the appearance of a simple arch structure and to face it with a matrix of red granite from Picton Island in the St. Lawrence River. Later it was decided to color the mortar with iron oxide, not a fortunate proceeding, for the color is much inferior to that of the granite. The granite is now exposed in the rough panels and along the moldings, pilasters and bases where it is bush-hammered. The smooth surfaces are weathering gradually and after a time the difference of color will be less pronounced.

The mechanical design of the structure is interesting. The arch is solid and perfect in condition save a fine vertical crack in the parapet over the haunches. This is a shrinkage crack and it occurred soon after construction. Its position could have been predetermined by a joint.

The whole arch was formed continuously without any intermission night or day, and has thus far been wholly impervious to water; no waterproofing was used.

Because of the deflection and vibration of the plate-girder a longitudinal joint was constructed along the face of the arch and adjacent to the plate-girder to avoid cracking. The joint was filled with oakum and an asphalt mixture, but it will not stay in place. The motion of the steel span causes it to work upward out of the joint.

The false soffit under the plate-girder is divided into three sections. The center is a part of the concrete floor slab. Ten ft. 8 in. each side of the center is a transverse joint. From the joint to the springing line the soffit is a sheet of mortar 3 in. thick plastered on woven wire. The wire is supported by a frame work of light channels. Provision is made for motion at the transverse joints. The concrete parapet or face of the false arch is separated from the concrete floor slab by a vertical joint. These joints have thus far prevented injury to the concrete by the vibrations from passing trains.

EUCLID AVENUE BRIDGE.

At Euclid Avenue the tracks cross the street on a four-degree curve, the tangent making an angle of 37 degrees, 29 minutes with the center line of the street. The street was depressed 3 ft. 6 in., and the railroad grade elevated 14 ft. 4 in. This street was made a controlling point in the grade line, the prime object being to avoid as far as possible any ob-

struction to the view along the avenue. In this respect the result is quite satisfactory as may be seen in Fig. 14.

Preliminary studies indicated that a plate-girder bridge with curb

FIG. 14—EUCLID AVENUE BRIDGE.

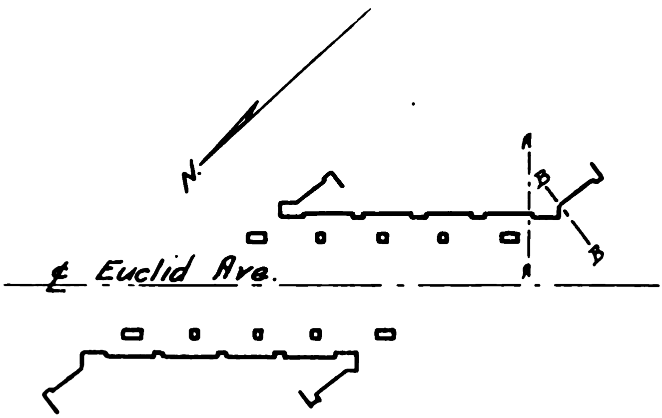


FIG. 15—DIAGRAM EUCLID AVENUE BRIDGE.

supports was the only feasible design. Sketches were made for trusses spanning the whole street, but they were objected to as unsightly. The clear span measured on the skew is 140 ft. 3 in. Because of the curve

it was necessary to space the girders 19 ft. center to center. The heavy live load and the enormous dead load together with the lateral clearance needed because of the curve, made the use of curb supports imperative.

Solid shale rock was found 27 ft. below the old street surface. It was overlaid with water-bearing sand, the depth of water varying with the season, but being generally about six ft. A concrete pier was constructed under each of the girders on the curb line, 10 piers in all. The inside piers are 6½ by 6 ft. in plan, and carry an estimated maximum load of 17 tons per sq. ft. The sidewalk spans are so short that the abutments are little more than retaining walls. Their load is trifling, but to insure against settlement which might injure the concrete superstructure they were founded on piles.

The thickness of the floor 3 ft. 6 in., top of rail to underside, was agreed to with the city officials a long time before the passage of the ordinance, before the live load and unit stresses were determined and before the type of bridge had been selected.

When the design of the structure was taken up it was soon found that the depth of floor allowed was very scant. A minimum thickness of ballast of eight inches had been agreed to as necessary to prevent noise and avoid damage to the concrete. The summit of the grade had been located on the bridge so it was not desirable to raise the grade.

These conditions are stated in detail, because, although investigations had indicated that waterproofing the floor slabs was in ordinary cases unnecessary, in this case the span was pretty long, there was no fall to take water away from the bridge and cracks in the floor were bound to occur over the curb supports. Had there been sufficient depth of floor available to waterproof the slab and give it a protective covering, such a course might have been followed. As it is, the leakage at the curb line is considerable.

The bridge was constructed without at any time closing the street. One street car track and one side of the roadway were abandoned at a time while depressing the roadway.

The inside girders weighed 79 tons and measured 91 ft. 3¼ in. over all. They were placed with a derrick car from above.

The form of the bridge in plan is a rhombus, the diagonals being respectively 83½ ft. and 245½ ft. Some trouble was expected from temperature changes and there was no disappointment. Both ends of the structure were left free on the abutments. The tops of the abutments were finished smooth and well painted with a heavy asphalt paint. The floor slab was then extended over the abutments. There has been a little motion on the top of each abutment; just enough to crack the mortar in the angle between the floor and the abutment face.

The greatest motion has occurred at the extreme apices of the rhombus. At the northerly apex the motion has resulted thus far in a few cracks that are hardly noticeable. At the southerly apex, in February, 1912, a crack appeared in the face of the pilaster, extending from the upper right-hand corner to the lower left-hand corner. An expan

sion joint had been constructed in the abutment at A and one at B (Fig. 15).

The joint at B did not appear to work. It was naturally assumed that the crack was occasioned by the tendency of the wing walls to part from the head wall in the angle, which is a common occurrence in abutment masonry. To remedy this the wing wall was cut loose from the head wall during the following summer by drilling clear through the abutment at B. The crack in the pilaster was then filled to a depth of two or three inches. In the winter of 1912-13, the crack again opened. Further repairs are now being made. The portion of the pilaster below the bridge seat and between the crack and the joint A has been removed and rebuilt, using reinforcing and dowels in the old concrete. At the bridge seat two grillages made of rails have been placed, one bearing on the other, the rail heads in contact. In this way it has been sought to provide a sliding surface of less resistance, it being thought that the pull of the bridge in cold weather was the cause of the crack.

The portion of concrete removed from the pilaster showed a projection from the face of about one-sixteenth-inch in extreme cold weather.

Another crack, and one which should have been avoided, occurred in the outside columns. The bridge proper is carried by steel columns encased in concrete and resting on concrete piers, carried to the rock foundation as above stated. The concrete facias concealing the bridge rest on the outside columns, but the columns were elongated in cross-section with concrete, that being sufficient to carry the load. In each of the four outside columns the concrete has parted from the steel. The crack is, as yet, barely visible. Now that it has happened, it is clear that steel reinforcing should have bound the concrete under the fascia to the steel column under the girder, even though the composite column does have a solid rock foundation.

BRIDGE FLOORS.

It was required that the railroad bridge floors be relatively noiseless and waterproof. In former years every effort has been put forth to build shallow floors so as to minimize the change of grade. Such floors have always permitted the muddy water to seep through upon people passing below and have operated as drums in accentuating every sound from the passing trains. To overcome these defects the floors were made of I-beams and concrete slabs upon which tracks were laid and ballasted as upon the ground. Such a design requires a greater depth of floor, which means a greater change of grade, and more steel to carry the added weight of concrete. The bridge is therefore more expensive. But in cities where the noise is troublesome, the ballasted floor is a great improvement. Trains passing over such floors are noticed but little more than when passing over the solid ground.

A concrete floor slab can also be made reasonably water-tight. The writer's first experience with concrete was on the Missouri in 1887-88.

Later it was used a little on the New York State Canals, and still later in bridge construction on the Nickel Plate. During this period many experiments had been made and papers written in which it was sought to demonstrate that concrete can be made practically impervious to water, and also that it cannot. Much concrete had been built that was very porous and there had sprung up numerous business enterprises for the manufacture and sale of waterproofing material. Both observation and experience indicated that water-tightness could be secured by either concrete alone or in combination with waterproofing. The requisite seemed to be that the material and workmanship should be the very best. If poor waterproofing were placed over poor concrete, the structure would leak. If the concrete were good, it would hold water, either with or without the waterproofing.

In order to confirm these opinions before construction, an investigation of concrete practice on other roads, and in building work, was undertaken by Mr. G. H. Tinker, Bridge Engineer, New York, Chicago & St. Louis Railroad. Later, as Chairman of the Committee on Masonry

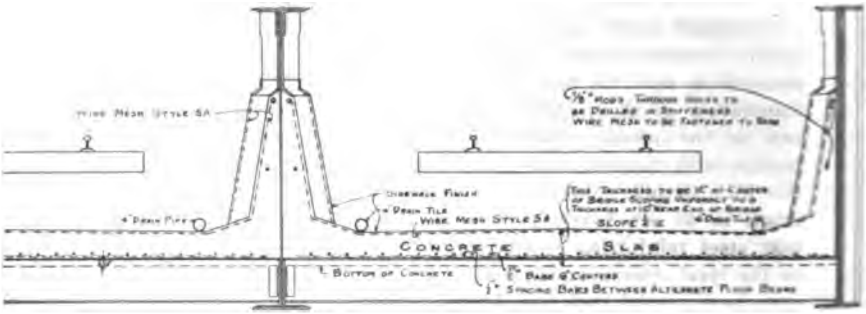


FIG. 16—SECTION OF BRIDGE FLOOR.

of the American Railway Engineering Association, he had exceptional opportunities for continuing the study. The result of this work was in harmony with the above-stated views and the bridge floors were accordingly designed without waterproofing. A paper by Mr. Tinker setting forth briefly the information he has accumulated appeared in Vol. 5, No. 3, of the Journal of the Cleveland Engineering Society. The following extract is quoted therefrom:

"In the bridges recently built in Cleveland by the Nickel Plate no foreign waterproofing substance has been used. An attempt has been made to construct a concrete slab which would be in itself as nearly waterproof as is practicable or desirable to make. This has proved satisfactory. When the Cedar Avenue bridge floor was built, the ends of the bridge were dammed up, the trough so formed was filled with water and allowed to stand for several days. No water whatever came through at any point of the slab. A little water ran through the dam and down over the back wall, and seeped through the joint between the bridge seat and floor slab. At the center bent there is a drainage system provided to carry what water might percolate through at that point down to the

gutters. Through some slight defect in the formation of this drainage some water seeped through there and dampened the concrete, but at no point of the bridge did any water drip."

Especial efforts were made to avoid the entrance of water between the steel and concrete and at points of contraflexure and where cracks might develop from temperature changes. Bevel flashings of steel were riveted to the girder webs and malleable cast flashings were fitted around the stiffeners to cover and seal the edge of the concrete (Fig. 16). This

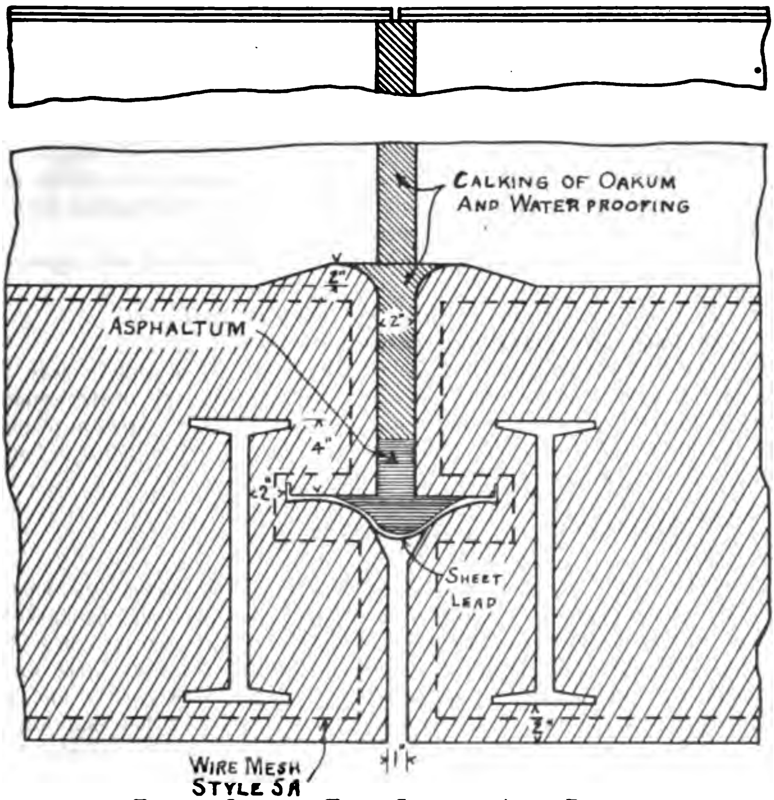


FIG. 17—JOINT IN FLOOR SLAB FOR ARCH BRIDGE.

design was very successful. At points of contraflexure over curb supports and at Cedar Avenue over the center columns it was realized that cracks would develop and an attempt was made to forestall their appearance by the construction of joints. The joints were carefully provided with gutters and drainage pipes, and it was hoped that no trouble would be had with the water. The cracks were successfully forestalled, but the drainage was unsuccessful. The channels soon became clogged with cinders and the details of steel work in the cross-girders did not leave

room for a sufficient body of concrete, and in some instances the concrete proved imperfect. So, while the slabs proved generally tight, there has been some leakage at points of contraflexure.

Much reliance had been placed on the use of direct labor and carefully selected foremen, but there came a great rush of work at a critical time and the floors suffered. In East Cleveland at a later date it became necessary to build waterproof joints at the hinges of the arch bridges. This was successfully accomplished in the manner shown in Fig. 17.

The concrete in the floor slabs cost about $12.00 per cu. yd., in place.

Now that the bridges are completed and have been two or more winters in service, the conclusions are as follows:

1. Concrete can be made water tight, under low heads, for all practical purposes.

2. The mixing, placing and ingredients of concrete are subject to such a great number and variety of defects that only the keenest attention will secure an impervious structure.

3. Contraflexure, temperature changes and settlements will produce cracks.

4. It is best to forestall cracks with predetermined joints.

5. Joints may be sealed against water if well-designed.

The highway bridges were paved with brick. The gutters have a good fall and the water runs off quickly. On the under side of the bridge floors the concrete is protected from locomotive blasts by cast-iron plates ½ in. thick and 36 in. wide. They weigh 71 lbs. per linear foot, and cost $5.23 per foot in place.

ORNAMENTATION OF BRIDGES.

Both cities insisted that the bridges be of an ornamental character. In Cleveland that idea seemed to mean that the structures must be masked with concrete. Steel was held to be unsightly, but concrete was in high favor. The bridges over East Boulevard and Cedar Avenue were surrounded by park land of considerable beauty. Euclid Avenue is known throughout the world as a magnificent residence street, but that magnificence is now largely a matter of history. Other streets, undefiled by business blocks, and exhibiting a more lavish display of wealth, have wrested its proud eminence and the solicitude for its waning glory is something like the reluctance with which a boy lays aside his copper-toed boots; it is done with a struggle. In this case the bridge is the evidence of the struggle.

In East Cleveland the municipal artist pinned his faith to a steel arch.

The Euclid Avenue bridge is shown in Fig. 14. The bridge at East Boulevard (Figs. 19, 20, 21) and the one at Euclid Avenue have been described in detail. The Cedar Avenue bridge (Figs. 22 and 23) was first designed and planned as a type. It is a set of plate-girders masked with concrete. The aim in its design was to secure a pleasing effect

FIG. 18—ARCH BRIDGE AT EDDY ROAD.

FIG. 19—EAST BOULEVARD BRIDGE.

FIG. 20—EAST BOULEVARD BRIDGE.

FIG. 21—EAST BOULEVARD BRIDGE.

FIG. 22—CEDAR AVENUE BRIDGE.

FIG. 23—CEDAR AVENUE BRIDGE.

from general lines and without fineness of detail. The restrictions of space for the roadway prevented that freedom of treatment which is necessary to secure the best results.

The writer has always felt a strong repugnance to the use of stone as a beam. Such a beam is not self-supporting and can never be more than a symbol of deception. Accordingly he tried to relieve the curse by giving the fascia the form of an arch, but while the curve of the soffit is somewhat pleasing, the required clearance for the roadway prevented a rise that would afford much resemblance to an arch.

The concealment of the steel work by the concrete is likewise a deception and would furnish an excellent theme for a tirade by an artist of Ruskin's school. However, it is noticeable that more pretentious structures are not free from such faults and it is probable that the minds of the people of Cleveland Heights are not disturbed thereby.

At Cedar Avenue the adjoining arch for Doan Brook and the railing of the small highway bridge in the foreground enhance the appearance of the structure.

The reddish color of the East Boulevard bridge, designed about a year later, resulted from some criticism of the glaring whiteness of concrete.

The elevation of the concrete fascia of the Mayfield Road bridge, Fig. 24, was designed in the office of Robert Hoffman, Chief Engineer, Department of Public Service. In this case the concrete fascia is built directly upon the outer girder, and it was desired to cover the stiffener angles and secure a pleasing effect without the use of too large a mass of concrete.

In East Cleveland the artists were not so active. The attitude was rather a stubborn opposition to everything proposed by the company. Steel arches were demanded because of the one formerly used at East Boulevard, and a type of iron railing was designed and adopted by the council. The company was finally able to avoid all but seven of the arches. It had little interest in the railings. Now that the bridges are completed the consensus of opinion locally is in favor of the plate-girders, and it is admitted that the lines of the railings are too fine.

The band of concrete—a concrete beam—used with the plate-girder spans is another effort at concealment (Fig. 25).

Apart from questions of beauty the recesses in the abutments for the shoes of the arch bridges are found to be a loitering place for boys and a receptacle for rubbish and filth.

RETAINING WALLS.

Numerous retaining walls were required to prevent encroachments of the embankments on private property. Fig. 26 shows a wall along the land of the Peerless Motor Car Company. This company built an iron fence on the right-of-way line at the beginning of the work and refused

FIG. 24—MAYFIELD ROAD BRIDGE.

FIG. 25—SHAW AVENUE BRIDGE, EAST CLEVELAND.

to sell a slope right or a parcel of land. In order to care for the requisite number of tracks a cross-section of roadbed and retaining wall, as shown in Fig. 27, was adopted. The wall was built, the track depressed and switching service to three industries maintained on the line adjacent to the wall without disturbing the fence. The length of the wall was 490 ft. Its cost was $7.09 per cu. yd.

It should be said that the above wall is next east of Ninety-third Street where the track depression began.

A larger wall built for similar reasons along the property of the Stearns Automobile Company was described in the Cornell Civil Engineer for March, 1913, page 336. This is a reinforced counterfort wall resting on piers (Figs. 28 and 29). The face is vertical and resistance to overturning is secured by attaching the counterforts to a slab resting on the piers and placing the embankment and tracks over the slab. The estimates showed a saving of about 20 per cent. over the cost of a gravity wall. The cost per cu. yd. was $6.55.

TRESTLES.

Pile trestles were used at nearly all of the street crossings. In East Cleveland there was one continuous trestle about 2,600 ft. long. All trestles over the streets were constructed to carry regular traffic. Track stringers and ties were used repeatedly at the several crossings.

The long trestle cost $9.40 per linear foot and after filling a credit of $3.25 per linear foot was made for the timber removed, making the net cost per foot $6.15.

Several trestles were constructed to serve private industries from the elevated tracks.

A common land driver was used for the long trestle. A Bucyrus mounted driver was borrowed from the railroad company on one occasion and later pendulum leads suspended from the boom of a locomotive crane were used (Fig. 30). The latter device was described in Engineering News, November 23, 1911, page 625, and erroneously credited to a contractor. Its particular merit is that the leads can be readily laid aside and the crane used for handling timber or even for shifting cars. Its mobility is much greater than that of the Bucyrus driver. For driving a large number of piles it would not be economical, but in building a trestle out from a bank as the piles are driven, it is very efficient. The rig was devised and used by the bridge foreman, John Kopp. The cost of the leads was $211.00.

At Mayfield Road much entertainment was furnished the local residents by excavating a deep hole in hard shale underneath the tracks and supporting them with a trestle. It was many months before the steam shovel, in excavating the subway, was ready to pass beneath the tracks, and meanwhile the people were permitted to contemplte the strange proceeding of digging a trench to make a place for a bridge (Fig. 5).

FIG. 26—RETAINING WALL.

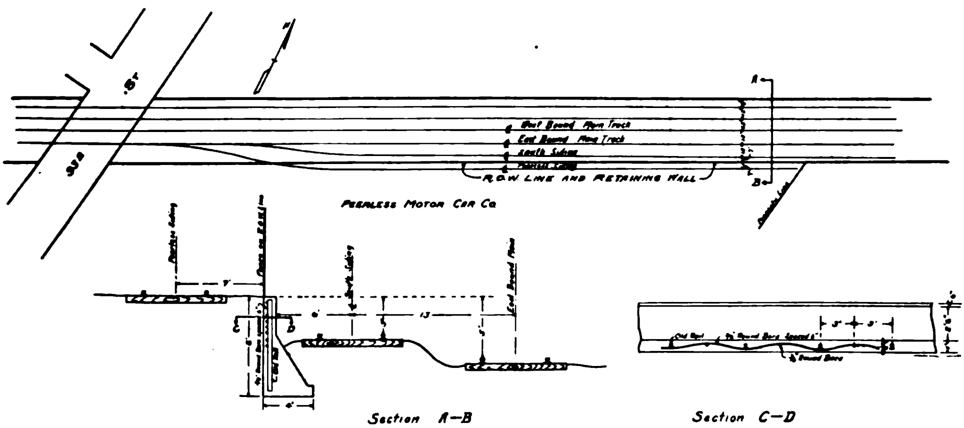


FIG. 27—CROSS-SECTION OF TRACKS.

STREET GRADES AND PAVEMENTS.

In Cleveland it was generally held by the city officials that changes of street grades should be so made that the maximum rate would be 4 per cent. In some cases this could not be done without material alterations in the proposed railroad profile and an increase in the ruling grade. The street crossings where this condition prevailed were all located along the base of a hill upon which is located the suburban village of Euclid Heights. The ascent of this hill involved much steeper grades, and so there was little to be lost in using street grades in excess of the desired maximum. At Cornell Road a 5 per cent. grade was agreed upon. At Cedar Avenue it was necessary to use a 6 per cent. grade, and at East Boulevard the grade is 10 per cent. As a matter of economy to the railroad company the steeper grade would make the shorter change in the street surface, which, besides the saving in construction, would incur a fewer number of damage claims for change of grade. As a slight offset to this, stone block pavement at cost of $2.77 per sq. yd. was required when the grade exceeded 4 per cent. The brick paving, used elsewhere, cost about $1.07 per sq. yd.; but these questions of economy were given no weight in determining the grades.

At Cornell Road it was found advantageous to alter the alinement, throwing the track about 65 ft. farther south. This change served to lessen materially the extent of the alteration in the street grade.

In East Cleveland the problems were very simple. In each case the original roadbed gave a slight hump to the street profile and it was generally sufficient to cut off that hump, leaving the new grade line nearly straight (Figs. 38, 39, 40 and 41).

In Cleveland the pavement was generally laid on a six-inch concrete base. In East Cleveland the earth is generally very sandy, and in such cases the brick was laid directly on the sand. Pavements laid in this way have given good results. On a few streets where the subsoil was clay, a six-inch concrete base was used.

At East Boulevard a good macadam pavement 12½ in. thick was constructed by a local contractor.

The costs of the pavements are about as follows:

Medina stone block (concrete base not included), 30.8 cents per sq. ft.—contract work.

Vitrified brick (concrete base not included), 11.84 cents per sq. ft.—contract work.

Vitrified brick, sand foundation, 11.9 cents per sq. ft.—direct labor.

Macadam, 19 cents per sq. ft.—contract work.

Concrete base, 6 in. thick, 6½ cents per sq. ft.—contract work.

WATER PIPES.

All water pipes encountered in the work were lowered to a minimum depth of six feet below the new street grades. The work was done generally in Cleveland by the City Water Department and by day labor. On numerous occasions where trenches were to be dug the company was re-

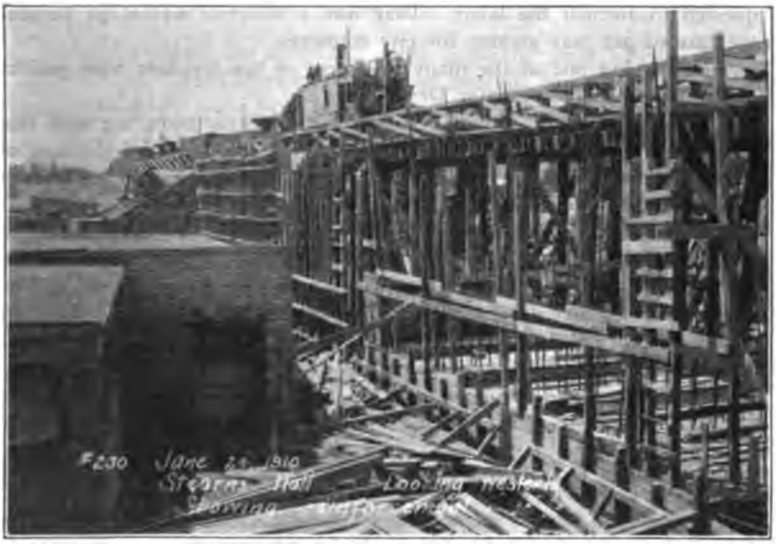


FIG. 28—RETAINING WALL.

FIG. 29—RETAINING WALL.

quested to furnish the labor. That was a material advantage because the rate of pay was greater for city employés.

This is but one of the many evidences of the freedom from politics of the Cleveland City Water Department.

The methods of accounting in the Water Department are such that where a street was vacated, the company was charged with the cost of the old water line, and where a new street was opened, the new water line was built without expense to the company.

A considerable loss was incurred on one occasion by the cracking of a number of sections of 36-in. main when burning out the lead. An ex-city employé had been hired as a foreman and on the advice of an employé of the Water Department he was permitted to take up the pipe. In his zeal to make a good showing he cooled the pipe with water which caused the cracks and rendered the pipe useless.

There were two 36-in. mains, both of which intersected the deepest cut and their depression in hard shale was very expensive.

SEWERS.

There were sewers to be lowered or diverted in nearly all of the streets crossed. In East Cleveland the work was generally simple. Where there was room below the pavement to cap a sewer with six or eight inches of concrete, no depression was made. The concrete cap was used for depths less than 2½ ft. from the top of sewer to surface of pavement.

From Hower Avenue to Superior Street, East Cleveland, a sewer extended parallel to the track and under the proposed embankment. It was located on private land that was purchased for additional right-of-way. This sewer was relocated on the southerly side of the new embankment. It consists of a 15-in. clay pipe about 20 ft. below the ground surface and 1,761 ft. long. Its cost was $7,089.53, or $4.03 per ft. The bottom of the trench was in shale for a distance of 935 ft.

In Cleveland the sewers were without interest save in Quincy Avenue and East One Hundred and Fifth Street. In Quincy Avenue the depression was so great that the contractor did his work in a tunnel. The tunnel was 380 ft. long. The major diameter of the sewer was 4.23 ft.

The East One Hundred and Fifth Street sewer was 7 ft. 6 in. in diameter and so located that the bottom of the invert north of the railroad was above the final top of rail. Three rectangular channels shown in Fig. 33 were built beneath the tracks to carry the flow. In time of flood these channels will be under a low head. They are built of concrete and roofed with steel beams bedded in concrete. A depression was cut in the bottom of the sewer to drain the channels under the tracks. It extended about 1,000 ft. down the street. The excavation in the sewer was done without blasting and the material trucked out on small cars. The material was hard shale, brick and concrete. Fig. 34 shows how the sewer was expanded behind the abutments to connect with the rectangular channels. The work on this sewer was done by the company.

WALKS.

In Cleveland the sidewalks were generally built by the city contractor. In East Cleveland they were built by the company. In some instances walks were built in Cleveland by the company.

New sidewalks were constructed generally of concrete. Old stone flagging was relaid when found in good condition and not damaged in handling. In 1912 Cleveland had a general contract for sidewalks under which it paid 12 cents per sq. ft. for 2½-in. flagging laid. The usual price for flagging delivered on the ground was 10 cents per sq. ft. It cost the company 4 to 5 cents per sq. ft. to relay flagging with its own men. This included redressing when broken. The flagging was bedded in a 4-in. layer of cinders, the price of which is included in the cost of laying.

The price for concrete walks under the general Cleveland contract was 13 cents per sq. ft. Concrete walks built by the railroad forces cost a minimum of 15 cents. It was interesting to observe the differences in operations that tended to make up the difference in cost.

The company paid 18½ cents per hour for labor. It is not known what the Cleveland contractor paid. It probably was no less.

The company used sand at a cost of 88 cents per cu. yd., delivered f. o. b. at point where used. The contractor frequently used sand excavated from the site of the walk. Such sand was sometimes good. It was often mixed with loam and any discrimination in its selection was naturally in the contractor's favor.

The company built walks 5 in. thick and gave good measure. The contractor built walks 5 in. thick, but was careful that they should not overrun in thickness.

Some contract walks went to pieces the first winter. An examination indicated very little cement below the upper half-inch of the walk's thickness. Walks built by the company have not yet shown any such behavior.

The company walks were carefully jointed to care for temperature changes. The contract walks were marked so as to present a jointed appearance, but provision for actual motion was mainly by accident.

The forces used by the company were not organized to build walks, and engaged in such work intermittently and for short periods. The handling of material from cars to walks was seldom done in the most economical manner, because the sidewalks were inconveniently located with respect to the tracks on which materials were received. The controlling reason for the building of walks by the company was to expedite the work and to remedy bad conditions for street traffic.

SEEDING SLOPES.

The East Cleveland ordinance required that the slopes of the embankment be covered with grass. To do this in an economical manner was no little task. The material of which the embankments were made was sand, very poor clay and shale.

The slopes were finished with the best material available and then well seeded with bromus inermis and hard fescue, mingled with oats in the forepart of the summer and later with rye. These grasses are very hardy and thrive on poor dry soil. They make very little turf before the second year and the grain was used for protection during the first season. The slopes were generally seeded as soon as prepared, and if that happened in the fall, rye was used instead of oats, because the rye would live during the winter.

The slope of the embankment was 1½ to 1 and to hold the earth against washing by the rain strips of board were placed on edge along

FIG. 30—LOCOMOTIVE CRANE DRIVING PILES.

the slope, parallel with the track and about 2½ ft. apart. They were secured to small stakes and then covered with earth so as to be scarcely visible. The boards and the stakes were taken from old form material and from the wreckage of buildings which were removed from the right-of-way. No charge was made for such material.

The seeding in general was quite successful and at the end of the second season the slopes were well covered.

The cost of seeding as above described was about one-half cent per sq. ft. The area seeded was approximately 12 acres, and about 47½ lbs. of grass seed were used per acre.

GENERAL PROCEDURE—EXAMPLE.

There were three Cleveland ordinances. Two were passed December 28, 1908, the third was passed January 25, 1909. They provided that

FIG. 31—36-INCH WATER MAIN AT WOODHILL ROAD.

the work should be completed within two years. The East Cleveland ordinance was not passed until December 28, 1909. It likewise provided two years for the performance of the work. The excavation was in Cleveland and the fill was mainly in East Cleveland. The excavation, including the Quincy Yard and the Euclid borrow pit, amounted to 691,000 cu. yds. The embankment amounted to 537,000 cu. yds.

It was manifestly unwise to waste the material excavated, and no suitable spoil bank was available. Yet it seemed necessary to proceed with the work regardless of the situation in East Cleveland. It was possible to complete the work in Cleveland leaving a runoff from Euclid Avenue eastward to Lakeview Avenue, having a grade of about 1.2 per cent. Such a grade would of course require the service of a pusher for the westbound traffic.

FIG. 32—36-INCH WATER MAIN AT QUINCY AVENUE.

Under these conditions the work was not only slow and expensive, but any program laid out was necessarily tentative and adapted to only a part of the work.

With the passing of the East Cleveland ordinance, it became possible for the first time to treat the work as a whole, and thereafter it was pushed rapidly forward.

All traffic was operated for the first time over the new grade in Cleveland on November 1, 1910. In East Cleveland the new grade was

FIG. 33—105TH STREET SEWER UNDER RAILROAD TRACKS.

FIG. 34—105TH STREET SEWER BEHIND ABUTMENTS.

placed in service throughout the city November 22, 1911. The street work was practically completed in 1912 in both Cleveland and East Cleveland. Although the time of final completion in each city was delayed considerably beyond the limit of the ordinances, the rate of progress had given general satisfaction and there were no complaints. It was early seen that the company had started to carry out in good faith the obligations assumed, and a spirit of friendliness and co-operation developed which made the work very pleasant.

The various controlling features of the work had been carefully studied long before its beginning and a careful program prepared covering the territory from Ninety-third Street to Superior Street. If the uncertainties of 1909, due to the pending East Cleveland ordinance be excepted, it may be said that this program was followed very closely, and in accordance with a time schedule that was always determined well in advance of the work. Because of this systematic planning there was never any delay through lack of material, and never any reduction of force through lack of work.

In February, 1910, the concrete construction for the ensuing year was carefully mapped out and explained to Foreman Bisset. At the end of the year he had accomplished a little more work than was planned. The same thing happened in 1911.

In estimating the progress of the excavation the monthly output of the shovel was taken at 20,000 cu. yds. The maximum output was 43,245 cu. yds., but the assumed average resulted in a close conformity to the program.

The best example of the working of this program is the portion of the work covering the Euclid Avenue crossing.

The first move in construction was to build a temporary line for regular traffic from Cornell Road across Euclid Avenue to a point east of the Euclid Avenue station. This move was for the purpose of providing dumping ground from Mayfield Road to Lakeview Avenue, and to permit the construction of the Euclid Avenue bridge. All regular traffic was turned over this temporary line June 7, 1909. Material from the steam shovel was hauled over the old Euclid Avenue crossing until August 14, 1909. The crossing was then abandoned to permit work on the bridge abutments.

The location of the temporary line (Fig. 1) was such that a portion of the street might be depressed 3 ft. 6 in. as planned, and the two northeasterly girders erected, leaving space for street cars to pass under the girders, and by a sharp ascent pass over the temporary track at the street grade. The clear head room underneath the girders and the temporary trestle was 14 ft. 6 in. The street car tracks were spread to permit the placing of a trestle bent between them. After the partial depression of the street—by a city contractor—the pavement was relaid, part of it in temporary position, pending the removal of the railroad tracks from the street surface. The trestle (Fig. 35) was completed September 6, 1910. At this time enough of the abutments had been completed to permit the

erection of three girders. Five girders were used in the bridge. The two northeasterly girders were erected and made ready for traffic in September and October. On November 1, 1910, all traffic was turned over the bridge. The old track was taken up and the street depressed and repaved before winter. The ground was sandy, which fact was of great assistance to the work so late in the season when the weather was cold and wet.

It was a very difficult matter to get each party concerned in the street depression to move promptly and get the roadway in shape for winter. There were wire conduits, water and gas pipes to lower, paving to take up and relay, earth to remove, street car tracks to take up and relay and all street traffic to maintain. It was a busy time. Six weeks of patient, earnest effort were expended in getting everything in readi-

FIG. 35—TRESTLE OVER EUCLID AVENUE.

ness for the change on November 1, and there was efficient co-operation of the finest kind.

As soon as the flurry due to a change in running track had subsided, the third girder was erected and two tracks were then available over the street.

On March 18, 1911, the abutments were complete. The remainder of the steel work was then erected and in October, 1911, the concrete superstructure was all in place.

The turning of traffic over the bridge at Euclid Avenue involved the completion of a track at the new grade from Mayfield Road to Superior Street. Many other details were being followed up while the Euclid

Avenue crossing was under way. There were grading, trestle building, masonry, steel work and street work all in progress and all arranged without conflict or delay. Every important move was planned a long time in advance, and its date carefully fixed by a study of the progress made and the common need.

ACCIDENTS.

The record of derailments which occurred on the work consist of:
1. A derailment on the East Cleveland trestle near Lakeview Avenue on the night of January 19, 1911. The derailed car ran the full length of the trestle, and the train parted near Superior Street. No serious damage resulted.

2. A derailment occurred at Superior Street, just east of the Superior Street bridge, on September 10, 1911. Several cars were turned over the bank, resulting in a considerable financial loss.

FIG. 36—MAYFIELD ROAD—DERAILMENT.

3. A derailment occurred just west of the Mayfield Road bridge on the morning of December 5, 1911. The train parted and one of the cars in the rear end of the train bumped into and demolished the concrete end post on the Mayfield Road bridge (Fig. 36). No serious damage was done. There were six cars detached from the train by the failure of the coupling and the distance passed over by the remainder of the train, after the application of brakes, indicates an initial speed of twenty miles per hour. For those who have been building bridge fenders of

concrete to guard against damage to supports by derailments, this occurrence is of especial interest. The impact was that of six loaded freight cars running about twenty miles per hour. The speed was somewhat lessened after leaving the rails. In the final impact against the concrete bridge railing, the post cracked clear through horizontally, but was not dislocated, and the railing was split a total length on the far side of 12 ft. 6 in., on the near side 7 ft. 6 in. The body of the post was 2 ft. 1 in. square. The railing was 1 ft. thick in the panel and 2 ft. wide at the top. The upper part of the railing was reinforced by four longitudinal bars ¾ in. in diameter. The panel was built over American Steel & Wire Co. 7-A woven wire.

These derailments were occasioned by too great speed, in spite of the fact that slow boards were in position on both sides of the points where the derailments occurred, and that the slow orders had been bulletined by the Superintendent. The trains were all freight trains and no serious personal injuries resulted.

On August 17, 1910, a locomotive crane was upset and fell from the trestle in East Cleveland to the soft embankment below. The crane had been hoisting earth in skips from a foundation and was overbalanced. The engineer admitted that he had used poor judgment in handling the load. He jumped from the cab as the machine overturned and escaped with a few bruises. No one was injured. The repairs to the crane cost $1,414.38.

On July 8, 1912, a crane was overturned while dismantling a steam shovel. The track on which it was standing, a pit loading track, was badly out of level and when the weight of the dipper came on the boom of the crane, the latter swung round in spite of attempts to hold it, and the crane was upset. The engineer jumped, no one was injured and very little damage was done.

PERSONAL INJURIES.

It is the belief of the writer that a large number of personal injuries are due to the impatience and thoughtlessness of foremen.

A nervous, impatient, blustering foreman keeps his men excited. A team of young, high-strung, powerful horses once belonging to the writer were described by their driver as very unsteady and hard to control. A later driver said the horses were as steady as a team of oxen and that he could do anything with them. The spirit of the latter driver is to be desired in a foreman. He should always be master of the situation, calm, self-reliant and resourceful, having complete and constant control of his men and being always alert for their safety. Men working in large gangs are subjected to danger not alone because of their own acts, but by the acts of their co-workers, and it is vitally essential that the foreman should have their safety constantly in mind. There are many other dangers not growing out of the presence of co-workers, but which bring disaster through errors of judgment. Such conditions require the

presence and direction of a man of large experience and superior judgment.

It too often happens that in his zeal to accomplish much work the foreman is careless of his men and leaving them to rely upon their own resources, keeps them in such a state of fear as to defeat his efforts to make progress.

Upon the work described these facts were duly impressed upon all the foremen. They were told that they were responsible for the safety of their men and that they must strive to avoid injuries. Occasionally comparisons were made of the number of accidents in different gangs, but no data was ever secured that tended to prove one foreman more careful than another. The personal injuries appeared rather to be governed by the nature of the work in hand. Pile driving and trestle building seemed to give rise to the greatest number and concrete form building next. In the latter case, injuries resulted most frequently from stepping on nails in the old form material. Strong efforts were made to eliminate accidents from this cause. The workmen were repeatedly warned and the nails were pulled promptly after the forms were removed.

The most serious injury which occurred on the work was the mangling of a hand in the gearing of a Lidgerwood unloader.

The construction of bridges over trolley lines was especially difficult and dangerous. On three of the streets the trolley service was maintained continuously, with slight exceptions at East One Hundred and Fifth Street and Cedar Avenue, and the men working around the wires were repeatedly cautioned about the danger of electric shocks. The completion of the work without accident from this cause was a great relief to all in authority.

Another danger was that of collisions with trains on the street crossings. The danger was greatly increased by the construction work, and both flagmen and street gates were used for protection. It is a curious fact that, after providing the usual safeguards, danger was then due almost entirely to drivers of vehicles who would try to run over the crossings in front of approaching trains and in spite of warnings from the flagmen. Current comment seems to place all blame for injuries at such places on the railroads. It is chargeable more properly to the impatience of restraint so often exhibited by people who feel themselves either above or outside the law. Cleveland's Director of Public Service has argued for crossing gates instead of flagmen, because of lack of obedience to the flagmen's warnings. The writer has frequently seen drivers of vehicles endeavor to run beneath the gates as they were being lowered and instances have occurred where automobiles have run through the gates after they were down.

The total number of injuries reported was about 290, and the average total expense per case was $22.76. This includes injuries of the most trivial nature. Every known case was reported and recorded for possible use in the future. Even though an injury was trivial, it might

sometime lead to a damage claim and then a correct record of the facts would be useful.

Considering the extent and duration of the work it is felt that the number of injuries is not excessive.

ACCOUNTING.

Because of the somewhat complicated relations of the various interested parties and the general use of direct labor, it was early discerned that the accounting was an exceedingly important part of the task and that in the end a successful adjustment of the obligations of the parties might involve considerable difficulty. With this in mind, a careful study was made of the subject and many precautions observed to insure success. The first move was to secure assistants worthy of the highest confidence, the next to post them fully concerning the aims and results to hold in mind and the means for their attainment.

Payments for land or for legal claims were made by the Legal Department. All other bills were approved and vouchered by the writer.

A monthly statement of expenditures was made to the Auditor. The largest part was held in a suspense account, pending the completion of the work.

Expenditures by either city were submitted for the approval of the writer.

The bills for all material, supplies, tools or services were verified by the Division Engineer. Supporting papers were filed with every voucher.

FIG. 37—OLD BRIDGE AT FAIRMOUNT ROAD.

FIG. 38—ELBERON AVENUE, EAST CLEVELAND, BEFORE SEPARATION OF GRADES

FIG. 39—ELBERON AVENUE, EAST CLEVELAND, AFTER SEPARATION OF GRADES

It was the expressed purpose of the writer to make the record so clear, and to keep the unit costs so well within bounds that the final results would necessarily prove satisfactory. The successful achievement of that purpose has not yet been questioned.

The time of all workmen, whether in the employ of the railroad or any other corporation, was taken daily by the timekeeper. He also made or secured from the foremen distribution of labor. Payment for labor was made once per month. The rolls were prepared and the distribution checked in the writer's office.

A storekeeper was employed to disburse tools and material and to account for their use.

Records of progress were continually kept to insure that the desired rate was maintained, and to stimulate the workmen to put forth their best efforts. Records of cost were made to control the expenditures. No part of the work could continue unduly expensive without receiving early attention from the office.

In order to secure the necessary unit prices and to properly interpret the accounts, the latter were placed wholly in the hands of an engineer who had previous experience in such matters, and who had demonstrated his ability on the present work.

Some things often discussed as theories could not be treated with a precision to satisfy an analytic mind. The most conspicuous case was that of form material. The great bulk of this material was composed of 4 in. x 6 in. and 2 in. lumber. It was used many times, until worn out or cut up. In the beginning all lumber delivered to a certain structure was charged thereto, and when taken away, credited, first cost being used in each case. It was expected that this would work out all right in the end if we were careful to have little material on hand. But in the rush of work, form material sometimes disappeared or credits failed to be made so that in figuring the final unit costs, the form material used is not a true record. It was adjusted in the light of the best knowledge available. The same is true in a very much lesser degree of the concrete material. The record was not always perfect.

A distribution of earth was made by carloads and the average carload derived from excavation measurement.

The preliminary estimate of the cost of the construction work was $1,843,690. The actual cost was about 11.2 per cent. less than the estimate. Other work, not part of the general project, was done for the "Short Line," for private parties and for the Nickel Plate, which brought the total expenditure for construction up to $2,257,059.44.

The cost of engineering was 3.62 per cent. of the cost of construction. It includes salaries, stationery and repairs of instruments.

The cost of administration amounted to 3.69 per cent. of the cost of construction and included salaries, office rent, supplies and telephone service.

The total amount expended in the purchase of tools and equipment is $40,000.

The estimated value of material on hand at the close of the work is $7,000.

Unit prices, where given, include a proper proportion of overhead charges.

CONSTRUCTION CONTRACTS WITH THE CITY.

Contracts were let by the city of Cleveland for the superstructure and substructure of the Cornell Road bridge in June, 1909. It was completed September 22, 1910. A contract was similarly let for the abutments of the Adelbert Road bridge September 24, 1909. They were completed in September, 1910. The superstructure for the latter bridge was contracted for March 23, 1910, and was completed in May, 1911.

During the work on the above bridges the operations of the company's construction forces were disturbed considerably by the slowness of the contractors.

The depression of Cedar Avenue was the next work in order for the city to undertake. The only practicable way to dispose of the material to be excavated in the street was to haul it on cars to spoil banks along the railroad. Any delay in the work would interfere seriously with the progress on the railroad bridge over Cedar Avenue. Under these circumstances it did not seem wise to permit an independent contractor to get control of the job.

A condition of similar relation to the administration of the whole undertaking existed at Fairmount Road (Fig. 37).

The highway already crossed the track on an overhead bridge, but there was room between the abutments for only one track, where four were needed. It was necessary to close Fairmount Road and remove the southerly abutment before the steam shovel approached it from the west. Should the removal of the abutment be placed in the hands of a small contractor, it might readily happen that the whole grading outfit would be compelled to sit idly by and watch the removal of the old masonry.

With these conditions in mind, it was decided to bid on the city contracts and to bid low enough to make sure that the company was the lowest bidder. This method was tried at Cedar Avenue and later adopted in all city work except in paving and sewers. The paving in no way affected the operations of the railroad, and it was better to make use of independent paving organizations than to increase the work of the Grade Elimination Department.

These remarks apply only to the work in Cleveland, as in East Cleveland the ordinance provided that the company should do all the work.

The contractors who bid against the company suffered some inconvenience and expense for which there appeared to be no remedy.

Having taken a city contract in the name of the company, the writer had the unusual experience of approving as engineer for the company drawings prepared by the city for work to be done by him for the rail-

road company which held the contract. All payments under the contracts were made on estimates approved by the writer as engineer for the company and received by the writer as representative of the contractor. It was the most successful game of chasing the devil about the stump the writer has thus far encountered. The results seemed to be entirely satisfactory to all concerned except the unfortunate bidders.

The question as to whether the company should announce its intentions in advance of a letting and thus avoid the consequent disappointment of the unsuccessful bidders was carefully canvassed and decided in the negative.

LIST OF CITY CONTRACTS TAKEN BY THE COMPANY.

Quincy Avenue—Foundations; concrete; grading.

East One Hundred and Fifth Street—Foundations; concrete; grading; modifying sewer.

Woodhill and Fairmount Roads—Grading and concrete.

East Boulevard—Highway Bridge; Doan Brook.

Cedar Avenue—Grading; Doan Brook Bridge.

Mayfield Road—Grading.

OPPOSITION TO THE PROJECT.

The portion of the Nickel Plate which is paralleled by the "Short Line" passes along the Fairmount Reservoir and through the adjacent section of Wade Park, crossing East Boulevard, Doan Brook and Cedar Avenue. It then skirts the rear of the grounds of Adelbert College and the Case School of Applied Science on the east, crosses Euclid Avenue, and follows East Cleveland Cemetery to a point near the city line. In East Cleveland it next crosses a series of eight residence streets, occupied by medium-priced houses, and parallels Euclid Avenue at a distance of about 600 ft. throughout that city.

The original grade of the road in East Cleveland was nearly level. Approaching Euclid Avenue from the east for 1300 ft. there was an ascending grade of 7/10 per cent. Euclid Avenue was crossed on an uncompensated 4-degree curve and the grade continued to the summit in the rear of Adelbert College (Fig. 2).

The territory surrounding the college is a fine residence district, across the railroad to the southeast is Cleveland Heights, the location of many of Cleveland's finest houses, and East Cleveland is a city of suburban residences. It was but natural that people living in this region should strongly oppose the granting of increased railway facilities and a few active opponents of the project were quick to enlist their support. There was no denial that the "Short Line" was asking for a valuable franchise, but the project meant much for the future development of the city and the proposal to so construct the road as to eliminate all grade crossings without expense to the city seemed like a suitable return. The opposition took the form of a demand that the tracks be depressed beneath the streets in East Cleveland and thus, following the desired 3/10 grade, be low enough to permit a tunnel under the summit near the college. This with electric traction and

FIG. 40—EDDY ROAD, EAST CLEVELAND, BEFORE SEPARATION OF GRADES.

FIG. 41—EDDY ROAD, EAST CLEVELAND, AFTER SEPARATION OF GRADES.

ornamental bridges increased enormously the estimate of the cost, but worse than that, the grade line ran into a cut beyond the pumping station, too deep for consideration. The railroads could not accept the plan and the Mayor of Cleveland, Tom Johnson, was able to understand the reason. He did not hasten matters. There was a free and fair discussion in public of the merits of the plan and up to the last vote of the Council the outcome was uncertain. But the contest was one of logic and the company won.

The passage of the Cleveland ordinance had an important bearing on the situation in East Cleveland. The opposition felt that it was losing ground and that the passing of the desired ordinance was but a matter of time.

The work is now completed. The residents of East Cleveland are well pleased with the results and general satisfaction and harmony prevail.

Figs. 38 and 39 show the crossing of Elberon Avenue, East Cleveland, before and after the separation of grades. The house at the end of the street is facing Euclid Avenue, which runs parallel to the railroad.

Figs. 40 and 41 are similar views of the crossing of Eddy Road. The house on an elevation at the end of the street in the view of the grade crossing is the Cleveland home of Mr. John D. Rockefeller.

CHRONOLOGY.

1908	
December 28	Two Cleveland ordinances passed the council.
1909	
January 25	The remaining Cleveland ordinance passed council.
February 3	Organization of department begun.
March 1	Construction of temporary running track east of Mayfield Road began.
April 15	Steam shovel began work.
June 7	Train No. 6 was the last train to cross Euclid Avenue on the old main track.
August 26	Steam shovel began excavation in Cedar Avenue.
December 28	East Cleveland ordinance passed.
1910	
February 8	Temporary main Ninety-third Street to Fairmount Road placed in service.
February 24	Began concrete work with company force.
March 24	First train over new bridge at Cedar Avenue and new grade to Mayfield Road.
June 1	Steam shovel began work in Mayfield Road.
August 24	Traffic turned over new grade from Ninety-third Street to East Boulevard.
October 1	Steam shovel began work in Quincy Avenue.
November 1	Traffic turned over new grade from Mayfield Road to Superior Street.
	New grade in service in all Cleveland territory.

1911	
November 22	Traffic turned over new grade Superior Street to Ivanhoe Road.
	New grade in service throughout East Cleveland.
1912	
March 1	Steel work completed.
July 1	Operation of Cleveland Short Line Railway began.
October 1	Nickel Plate ready for double-track operation.

CONCLUSION.

The work is now complete. According to common standards, it may be considered a success. The people along the route are pleased with the result, the officers of the two municipalities have expressed their gratification, the four-track roadbed was completed before the "Short Line" was ready to lay its track; the transportation officials of the Nickel Plate are satisfied with the comparatively slight interference with traffic and the cost is below the estimate.

Under such circumstances it would be ungrateful to remember occasional defects and failures or to wish that any task had been better done.

The employes of the Department gave the most faithful attention to their work and strove diligently to excel in the tasks assigned. It is a pleasure to acknowledge here a large measure of indebtedness for their skilled and faithful assistance and to wish them the best success in their new positions.

To an Engineer it will be of interest to know that the writer attributes a goodly portion of the satisfaction of the Operating Department to his full realization that the first business of a railroad is to handle traffic. It is built for that purpose. After building it is obligated to its patrons to render good service and the funds for improvements are derived either directly or indirectly from that service.

To those who find this account lacking in some particular that has aroused their interest, it may be said that in its preparation the principal problem has been one of selection. Neither time nor space could be used to describe all of the interesting features of the work. If what has been written shall serve to refresh the memory and stimulate to further excellence like efforts of the reader, the paper will have served its highest purpose.

The General Manager of the Nickel Plate, Mr. A. W. Johnston, is a Civil Engineer. To this fortunate circumstance and his rare personal qualities of leadership can be ascribed much support and co-operation from other departments without which such a successful record would have been impossible. The writer also enjoyed the unqualified support of the President, Mr. W. H. Canniff, and of the General Counsel, Mr. John H. Clarke. Altogether he found more to enjoy in these four years of busy life and more loyal and harmonious assistance than might reasonably have been hoped, and he feels profoundly grateful to all who were concerned in bringing the work to a successful completion.

THE AIR-SEASONING OF TIMBER.

By William H. Kempfer,

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INTRODUCTION.

Air seasoning of timber means ridding the wood of part of its moisture by letting it stand in the open air. If seasoned long enough in this way, the moisture content of the wood will finally come into equilibrium with that of the surrounding atmosphere. This process takes place in any timber which has been felled or deadened, but the rate of drying varies with many factors, among them climate, time of year, species of wood, size and form of the piece, and degree of exposure. Certain of these factors may be controlled and others taken advantage of, so as to hasten the drying process itself, and also to minimize the injuries to wood involved in seasoning.

The objects of seasoning, briefly summarized, are:

(1) To prevent injury by insects and decay before the timber is put to use.

(2) To increase the durability of timber in service.

(3) To prevent shrinking and checking of the timbers in service.

(4) To increase the strength of the wood.

(5) To decrease its weight.

(6) To prepare it for treatment with preservatives, for kiln drying, and for other industrial processes.

Wood, while green, is especially susceptible to attack by insects and decay-producing fungi; on the other hand, wood seasoned too rapidly or unequally may check or warp so seriously as to render it worthless. It is, therefore, necessary to know the time required for wood to become air dry, and also the effect of factors which tend to increase or retard the rate of evaporation.

The data collected by the Forest Service on air seasoning pertain chiefly to the rate at which various species and forms of timber lose moisture when freely exposed to the atmosphere. Such information with respect to cross-ties, poles and sawed timbers has been obtained in a number of localities, representing various climatic conditions throughout the country, and for a large number of species, especially of the conifers. Much of this information, though already published by the Forest Service, is scattered among various circulars and bulletins; and other data, although collected a number of years ago, have not been previously published. To make this information available, therefore, it is here collected, and the results of the various tests are put into such form as to be, so far as possible, comparable with one another.

The data* on air seasoning have been obtained in connection with two distinct lines of investigations: (1) studies of methods to increase the durability of timbers; and (2) tests of mechanical properties of wood. In the first set of investigations green timbers, in the form of ties, poles and cross-arms, were dried so as to determine the effect of seasoning upon the wood's durability and upon its permeability. The tests were concerned primarily with durations of seasoning applicable to commercial timber yards. In the second set of investigations no special study was, as a rule, made of seasoning, but in some instances a record of the loss of weight was obtained on timbers received green and tested air dry.

INTERPRETATION OF THE SEASONING CURVES.

In the case of cross-ties, which furnish the greater portion of the data presented in this Bulletin, the rate of seasoning is shown by curves plotted from the average weights of the ties at successive periods. On account of the variation in the average size of the different lots of ties, the losses in pounds per tie do not afford as good a basis for comparison as percentage losses, or losses expressed in pounds per unit of volume. But the unit volume basis could not be applied, because in many cases the volumes of the ties had not been obtained, and the former was considered inadvisable because the percentage method is open to more errors than the method adopted. Freshly cut timber loses weight very rapidly in warm, dry weather—so rapidly that ties of some species lose ten lbs. in 24 hours. While in most cases the first weights were nominally the green weights of the timber, usually it was not possible to weigh the ties immediately after they were cut. As a rule, from one day to a week or more elapsed between the time of cutting and the time when the ties were brought to the yarding point and weighed. The first weights are therefore not strictly comparable, and the losses during the first stage of the seasoning process, which may or may not be shown by the weighings, would make an important difference in computed percentage losses. In the case of curves plotted from actual weights, neither their direction nor location is affected by failure to have the first weights of the ties comparable; the only effect of changes occurring before the first weights were obtained is to change the points of origin of the curves.

The rates of seasoning of the various species and lots of ties may be compared by the general trend of the curves. The approach of the ties to the air-seasoned condition is indicated in general by the approach of the curves to a comparatively horizontal position, except when this occurs at a time of the year unfavorable for seasoning; if it first occurs at such a time, the degree of dryness is not indicated unless the

*The experiments on which this publication is based were made in co-operation with various commercial companies and associations, and with educational institutions.

curves are continued through the unfavorable period into the succeeding favorable period.

The curves for other forms of timber are drawn similarly to those for ties, except that they are based on the weights per cubic foot, and are therefore more readily comparable with one another.

CROSS-TIES.

METHOD OF CONDUCTING TESTS.

The various experiments on tie seasoning differed in details, but they were conducted on the same general plan. The ties were procured at monthly intervals throughout the year and each month's cut piled in different ways so as to determine the effect of the form of pile on the rate of seasoning. Each pile consisted of 50 ties; these were exposed to the weather without cover, except in so far as the top tier of each pile served as a roof. The rate of seasoning was determined by weighing each tie individually, usually at intervals of one month.

It was found that the rate of seasoning from month to month did not vary sufficiently to warrant presenting the data for each month separately and adjacent curves for ties of two or three months which showed similar rates of seasoning were accordingly combined. Curves for the different forms of piles have also been combined when they showed little difference in the rate of seasoning, but data were omitted on piles which showed marked irregularity, such as unusually high or low average weight.

As a rule, the data for each pile were plotted separately and from these certain curves were selected and averaged to form the final curve. In many cases, however, the final curve could be attained directly by computing numerically the average weights.

SOUTHWESTERN WOODS.

The woods of the Southwest tested for seasoning were Western yellow pine, white fir and Douglas fir. Two forms of Western yellow pine were distinguished: the "black pine," the comparatively young, rapidly-growing trees; and the "red pine," consisting of the older trees. The ties were seasoned at Pecos and Rociata, New Mexico, which are between 7,000 and 8,000 ft. above the sea.

The monthly curves could be classified best in five groups, as follows: (1) January and February; (2) March and April; (3) May, June and July; (4) August, September and October, and (5) November and December. This grouping has been followed so far as comparable data on the different species were available.

The rate of seasoning is shown by Figs. 1 to 10, and in Table 1 are given the number and description of the ties on which these curves are based.

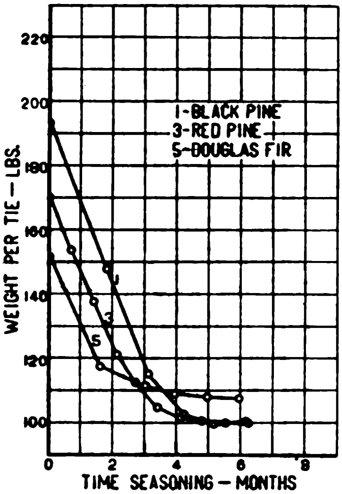
TABLE 1.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR SOUTHWESTERN WOODS.

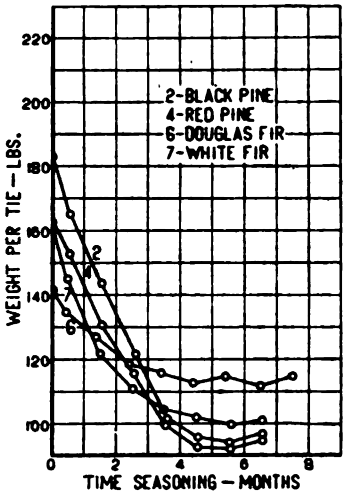
Ref. No.	Species	Locality	Date Cut	Form of Ties	Form of Piles	No. of Ties
1	Black pine (Western yellow pine)....	Pecos, N. M...	Jan. 1904	Hewn, 6"x8"x8'	7x2	50
1a	Black pine (Western yellow pine).......	Pecos, N. M...	Mar. 1904	Hewn, 6"x8"x8'	8x2, 8x1	150
1c	Black pine (Western yellow pine).......	Pecos, N. M...	Oct., 1903	Hewn, 6"x8"x8'	7x2	100
1d	Black pine (Western yellow pine).......	Pecos, N. M...	Dec., 1903	Hewn, 6"x8"x8'	8x2, 7x2	75
2	Black pine (Western yellow pine).......	Rociata, N. M.	Jan., 1904	Hewn, 6"x8"x8'	7x2	150
2a	Black pine (Western yellow pine).......	Rociata, N. M.	Mar., 1904	Hewn, 6"x8"x8'	4x4	150
2b	Black pine (Western yellow pine)......	Rociata, N. M.	May, 1904 June, 1904	Hewn, 6"x8"x8'	8x1	200
2c	Black pine (Western yellow pine).......	Rociata, N. M.	Aug., 1903	Hewn, 6"x8"x8'	7x2	100
3	Red pine (Western yellow pine).......	Pecos, N. M...	Jan., 1904 Feb., 1904	Hewn, 6"x8"x8'	7x2	100
3a	Red pine (Western yellow pine).......	Pecos, N. M...	Mar., 1904	Hewn, 6"x8"x8'	7x2, 8x1	150
3b	Red pine (Western yellow pine).......	Pecos, N. M...	May, 1904 June, 1904	Hewn, 6"x8"x8'	9x9, 8x8	465
3c	Red pine (Western yellow pine).......	Pecos, N. M...	Aug., 1903 Sept., 1903	Hewn, 6"x8"x8'	7x2	150
3d	Red pine (Western yellow pine).......	Pecos, N. M...	Nov., 1903	Hewn, 6"x8"x8'	8x2	50
4	Red pine (Western yellow pine).......	Rociata, N. M.	Jan., 1904	Hewn, 6"x8"x8'	7x2	50
4a	Red pine (Western yellow pine).......	Rociata, N. M.	Mar., 1904	Hewn, 6"x8"x8'	4x4	200
4b	Red pine (Western yellow pine).......	Rociata, N. M.	May, 1904 June, 1904	Hewn, 6"x8"x8'	8x1	376
4c	Red pine (Western yellow pine)	Rociata, N. M.	Aug., 1903	Hewn, 6"x8"x8'	7x2	100
5	Douglas fir..........	Pecos, N. M	Jan., 1904	Hewn, 6"x8"x8'	7x2, 8x1	100
5a	Douglas fir......	Pecos, N. M...	Mar., 1904	Hewn, 6"x8"x8'	7x2, 9x9	100
5b	Douglas fir..........	Pecos, N. M...	May, 1904 June, 1904	Hewn, 6"x8"x8'	8x8, 9x9	200
5c	Douglas fir.........	Pecos, N. M...	Oct., 1903	Hewn, 6"x8"x8'	7x2	100
5d	Douglas fir..........	Pecos, N. M.	Dec., 1903	Hewn, 6"x8"x8'	7x2	80
6	Douglas fir.......	Rociata, N. M.	Jan., 1904	Hewn, 6"x8"x8'	9x9	50
6a	Douglas fir......	Rociata, N. M.	Mar., 1904	Hewn, 6"x8"x8'	8x8, 9x9	95
6b	Douglas fir	Rociata, N. M.	May, 1904 June, 1904	Hewn, 6"x8"x8'	8x8	199
6c	Douglas fir........	Rociata, N. M.	Oct., 1903	Hewn, 6"x8"x8'	9x9	87

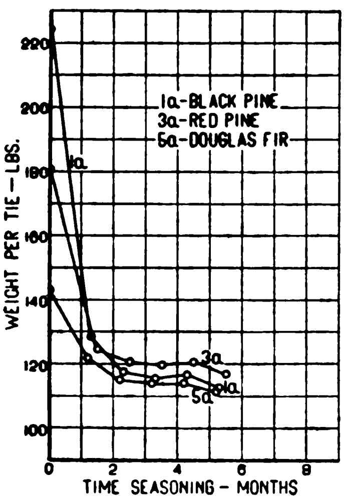
TABLE 1.—Continued.

Ref. No.	Species	Locality	Date Cut	Form of Ties	Form of Piles	No. of Ties
7	White fir (Abies concolor)............	Rociata, N. M. Pecos, N. M...	Jan., 1904 Jan., 1904	Hewn, 6"x8"x8' Hewn, 6"x8"x8'	7x2, 8x2 triangular	157
7c	White fir (Abies concolor)............	Pecos, N. M...	Sept., 1903 Oct., 1903	Hewn, 6"x8"x8'	7x2, 9x9*	200
7d	White fir (Abies concolor)............	Rociata, N. M.	Dec., 1903	Hewn, 6"x8"x8'	triangular	100

*Two outer ties of each tier set on edge.







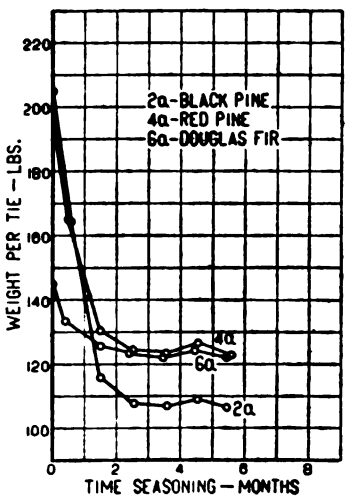
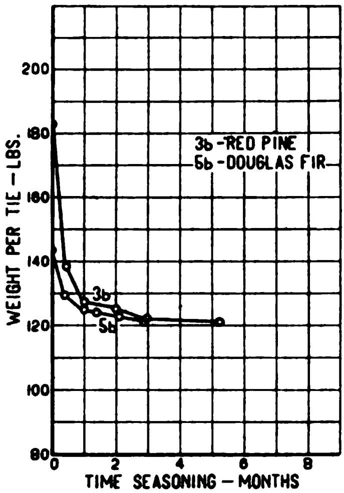


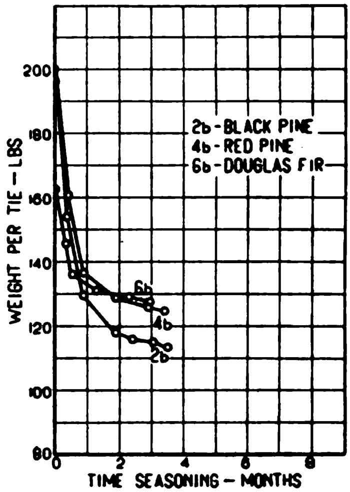
Fig. 1.—Seasoning of Ties at Pecos, N. M.; Cut in January and February.

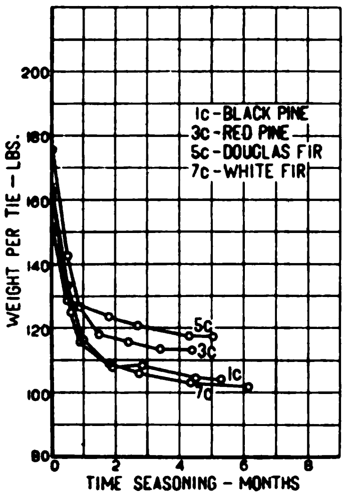
Fig. 2.—Seasoning of Ties at Rociata, N. M.; Cut in January.

Fig. 3.—Seasoning of Ties at Pecos, N. M.; Cut in March.

Fig. 4.—Seasoning of Ties at Rociata, N. M.; Cut in March.







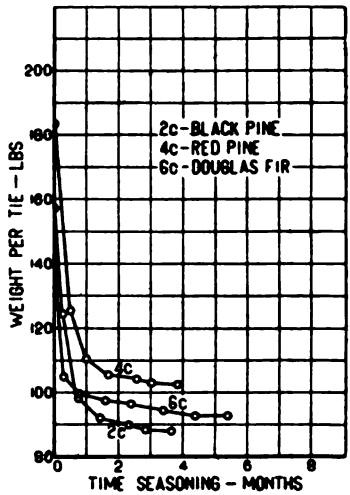


Fig. 5.—Seasoning of Ties at Pecos, N. M.; Cut in May and June.

Fig. 6.—Seasoning of Ties at Rociata, N. M.; Cut in May and June.

Fig. 7.—Seasoning of Ties at Pecos, N. M.; Cut in August, September and October.

Fig. 8.—Seasoning of Ties at Rociata, N. M.; Cut in August and October.

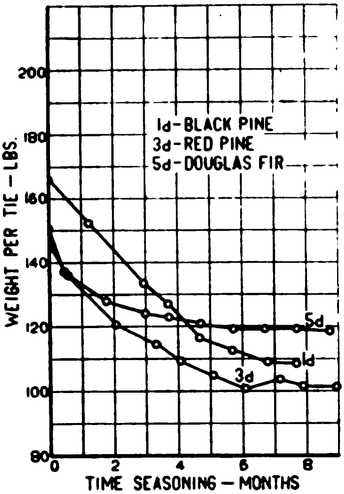


Fig. 9.—Seasoning of Ties at Pecos, N. M.; Cut in November and December.

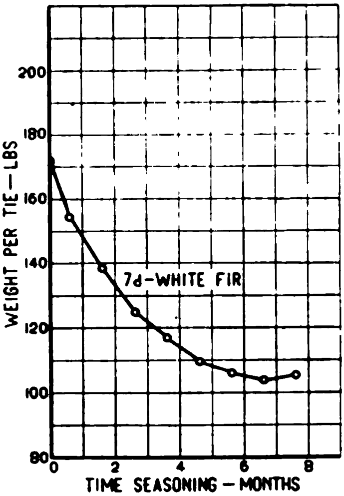


Fig. 10.—Seasoning of Ties at Rociata, N. M.; Cut in December.

Ties cut in January and February required from four to five months to reach a constant moisture content. As the season advanced the rate of evaporation very much increased. Ties cut in May and June required a much shorter time to reach constant weight; those tested at Rociata required two months; those at Pecos, only one month. Not much change occurs in this rate until November. The November and December ties reach a constant weight in about six months.

Very little difference was found in the rate of seasoning of black and of red pine, but the total loss of weight was usually greater for the black pine. This would be expected, because rapidly-grown trees generally contain more sapwood, and hence more moisture,* than the more slowly-grown trees of the same species. The curves for white fir resemble very closely those for the pines. Douglas fir seems to require about the same time to reach constant weight as the other species, but the weight lost is much less.

Pecos and Rociata have quite different exposures, though nearly the same elevations. The ties at Pecos apparently season a little more rapidly

*This applies to most coniferous woods, but not necessarily to the broad-leaved trees or hardwoods.

than those at Rociata, but since the seasoning at both places is very rapid the differences in time are not important.

From volume and weight determinations on sample ties, which had seasoned from 12 to 20 months, were obtained the air-dry weights per cubic foot shown in Table 2. The moisture content of the ties was not known.

TABLE 2.—AVERAGE VOLUME AND AIR-DRY WEIGHT PER CUBIC FOOT OF SAMPLE TIES—NEW MEXICO.

Species	Number of Ties	Average Volume	Weight per cubic foot (air dry)
		Cubic feet	Pounds
"Black pine"	82	3.5	33
"Red pine"	67	3.6	33
Douglas fir	76	3.3	33
White fir	50	3.5	31

NORTHWESTERN WOODS.

Seasoning curves (Figs. 11 to 15) are given for lodgepole pine, Western larch and Douglas fir, of the Northwestern species. The records on lodgepole pine were obtained at Bozeman, Mont., on Western larch at Sandpoint, Idaho, and on Douglas fir at Sandpoint, Idaho, and Pasco and Tacoma, Wash. A list of the ties on which the curves are based is given in Table 3.

TABLE 3.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR NORTHWESTERN WOODS.

Ref. No.	Species	Locality	Period of Cutting	Form of Tie	Form of Pile	No. of Ties
10	Lodgepole pine	Bozeman, Mont	Jan., 1903 Feb., 1903	Hewn, 6"x8"x8'	7x2	200
10a	Lodgepole pine	Bozeman, Mont	Mar., 1903 Apr., 1903	Hewn, 6"x8"x8'	7x2	200
10b	Lodgepole pine	Bozeman, Mont	May, 1903 June, 1903 July, 1903	Hewn, 6"x8"x8'	7x2	300
10c	Lodgepole pine	Bozeman, Mont	Aug., 1902 Sept., 1902	Hewn, 6"x8"x8'	7x2	200
10d	Lodgepole pine	Bozeman, Mont	Oct., 1902 Nov., 1902	Hewn, 6"x8"x8'	7x2	200
11	Douglas fir	Sand Point, Idaho	Jan., 1905	Hewn	7x2	50
11a	Douglas fir	Sand Point, Idaho	Apr., 1905	Hewn	7x2	50

TABLE 3.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR NORTHWESTERN WOODS—Continued

Ref. No.	Species	Locality	Period of Cutting	Form of Tie	Form of Pile	No. of Ties
11c	Douglas fir........	Sand Point, Idaho.....	Sept., 1904	Hewn	7x2	50
11d	Douglas fir........	Sand Point, Idaho.....	Nov., 1904 Dec., 1904	Hewn	8x1 7x2	150
12	Douglas fir....... (unpeeled ties)	Sand Point, Idaho.....	Jan., 1905 Feb., 1905	Hewn	7x2	200
12a	Douglas fir........ (unpeeled ties)	Sand Point, Idaho.....	Apr., 1905	Hewn	7x2	50
12c	Douglas fir........ (unpeeled ties)	Sand Point, Idaho.....	Sept., 1904	Hewn	7x2	100
12d	Douglas fir........ (unpeeled ties)	Sand Point, Idaho.....	Nov., 1904 Dec., 1904	Hewn	7x1 7x2 8x1	350
13	Western larch......	Sand Point, Idaho.....	Jan., 1905	Hewn	7x2	50
13a	Western larch......	Sand Point, Idaho....	Apr., 1905	Hewn	7x2 8x1	100
13c	Western larch......	Sand Point, Idaho	Oct., 1904	Hewn	7x2	50
13d	Western larch.....	Sand Point, Idaho.....	Nov., 1904 Dec., 1904	Hewn	7x2 8x1	150
14	Western larch...... (unpeeled ties)	Sand Point, Idaho.....	Jan., 1905	Hewn	7x2 8x1	150
14c	Western larch...... (unpeeled ties)	Sand Point, Idaho.....	Sept., 1904 Oct., 1904	Hewn	7x1	100
14d	Western larch...... (unpeeled ties)	Sand Point, Idaho.....	Nov., 1904 Dec., 1904	Hewn	7x2 8x1	400
15	Douglas fir........	Pasco, Wash...........	Jan., 1904 Feb., 1904	Sawed, 7'x9"x8"	7x2	400
15a	Douglas fir........	Pasco, Wash..........	Mar., 1904 Apr., 1904 May, 1904	Sawed, 7'x9"x8"	7x2	600
15b	Douglas fir........	Pasco, Wash...........	June, 1904 July, 1904	Sawed, 7'x9"x8"	7x2	400
15c	Douglas fir........	Pasco, Wash...........	Aug., 1904	Sawed, 7'x9"x8"	7x2	200
15d	Douglas fir........	Pasco, Wash...........	Oct., 1904 Nov., 1904	Sawed, 7'x9"x8"	7x2	400
16	Douglas fir........	Tacoma, Wash........	Dec., 1904 Jan., 1905	Sawed, 7'x9"x8"	7x2	400
16a	Douglas fir........	Tacoma, Wash........	Mar., 1904 Apr., 1904	Sawed, 7'x9"x8"	7x2	400
16b	Douglas fir........	Tacoma, Wash........	May, 1904 June, 1904 July, 1904	Sawed, 7'x9"x8"	7x2	600
16c	Douglas fir........	Tacoma, Wash........	Aug., 1904	Sawed, 7'x9"x8"	7x2	200
16d	Douglas fir........	Tacoma, Wash........	Oct., 1904 Nov., 1904	Sawed, 7'x9"x8"	7x2	400

Although climatic conditions in the Northwest are different from those in the Southwest, and vary also throughout the region, the same grouping of the ties could be employed at all places. In spite of differences caused by species and by local climatic conditions, a similarity exists in the curves for the various lots of ties cut at the same time of year. The effect, however, of the time of year when the tests are started is very evident.

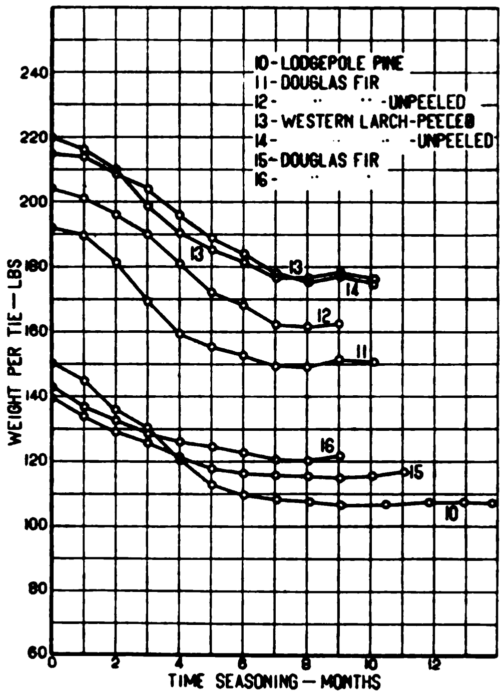


Fig. 11.—Seasoning of Lodgepole Pine Ties at Bozeman, Mont., Douglas Fir at Sandpoint, Idaho (Curves 11 and 12), Pasco, Wash. (Curve 15), and Tacoma, Wash. (Curve 16); and Western Larch at Sandpoint, Idaho; Cut in January and February. Tacoma Ties in December and January.

Lodgepole pine in Montana cut in May, June or July was practically air dry in three months, and even if started in September it became fairly well seasoned before winter; but, if started in winter, it did not become dry until July of the following summer. Larch in Idaho and Douglas fir in Idaho and Washington, if cut in the early spring, required from four

to five months to reach a condition at all resembling air dryness; if the ties were cut as late as July they lost almost as much moisture in the succeeding two or three months as they did by holding them over until the following summer.

The ties seasoned at Tacoma and Pasco, Wash., afford a good example of local climatic effects; both lots were from the same source

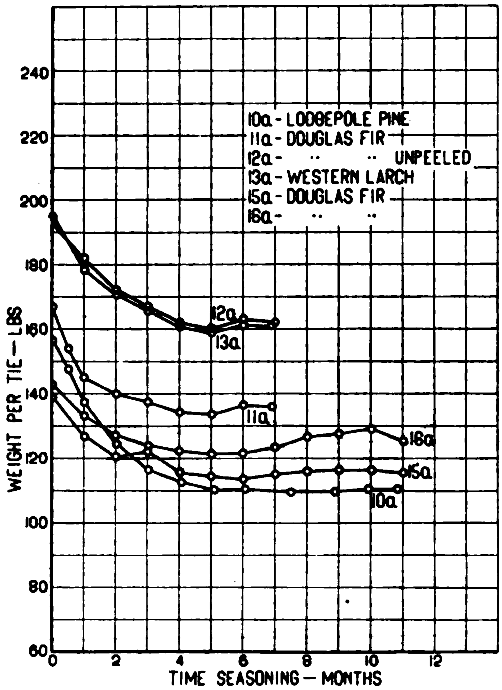


Fig. 12.—Seasoning of Lodgepole Pine Ties at Bozeman, Mont.; Douglas Fir at Sandpoint, Idaho (Curves 11a and 12a), Pasco, Wash. (Curve 15a), and Tacoma, Wash. (Curve 16a); and Western Larch at Sandpoint, Idaho; Cut in March and April. (Douglas Fir at Sandpoint, March, April and May.)

and the first weights were taken at the same time, but in each case the ties at Pasco lost weight faster and reached a lower weight than the ones at Tacoma. Also, the gains in weight, due to the absorption of water during the rainy season, which were noticeable in Tacoma ties, were absent or less pronounced in those at Pasco.

The Douglas fir ties seasoned at Tacoma and at Pasco were sawed to standard dimensions and had an average volume of 3.5 cu. ft. Assuming the oven dry weight of the wood to be 28.3* lbs. per cu. ft., the moisture content of the most thoroughly seasoned ties was 15 per cent. for those at Pasco and 16 per cent. for Tacoma. The corresponding weights for the two sets were about 33 lbs. per cu. ft.

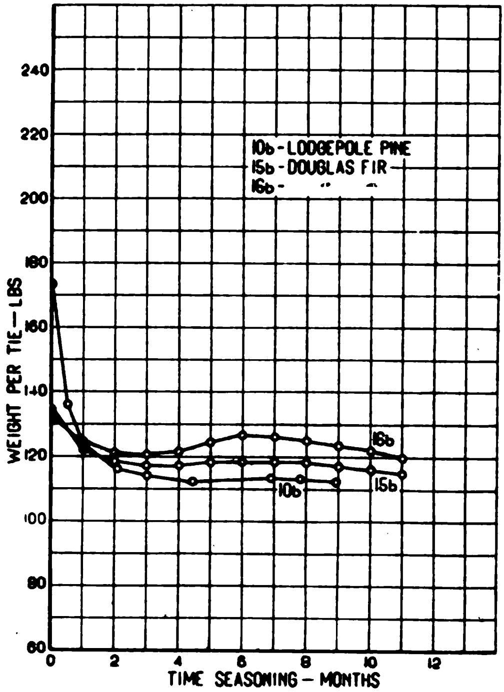


Fig. 13.—Seasoning of Lodgepole Pine Ties at Bozeman, Mont.; and Douglas Fir at Pasco, Wash. (Curve 15b), and Tacoma, Wash. (Curve 16b); Cut in May, June and July.

EASTERN CONIFERS.

The only Eastern coniferous woods on which seasoning records were obtained are hemlock and tamarack. Curves of their rate of seasoning are shown in Figs. 16 to 20, and a description of the times is given in Table 4.

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*Average as quoted in Circular 146, for a series of determinations on Douglas fir beams made by the Forest Service at the Berkeley, Cal., timber-testing laboratory. See also footnote (2), page 193.

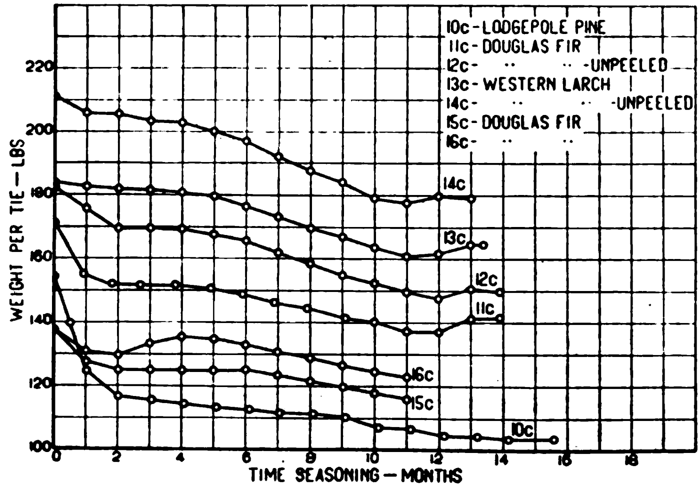


Fig. 14.—Seasoning of Lodgepole Pine Ties at Bozeman, Mont.; Douglas Fir at Sandpoint, Idaho (Curves 11c and 12c), Pasco, Wash. (Curve 15c), and Tacoma, Wash. (Curve 16c), and Western Larch at Sandpoint, Idaho; Cut in August, September and October.

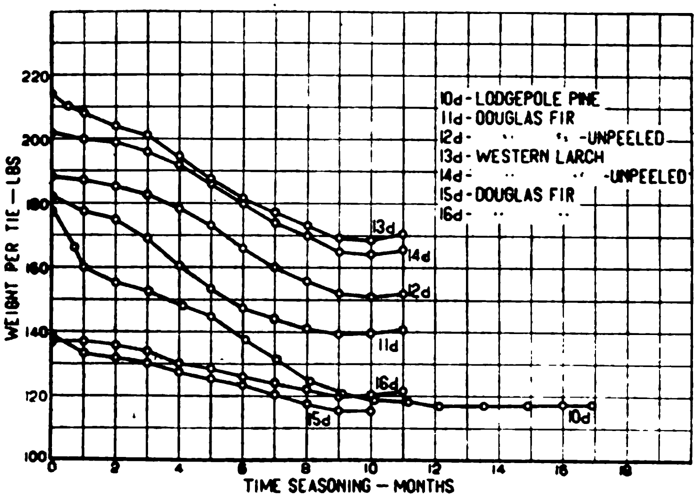


Fig. 15.—Seasoning of Lodgepole Pine Ties at Bozeman, Mont.; Douglas Fir at Sandpoint, Idaho (Curves 11d and 12d), Pasco, Wash. (Curve 15d), and Tacoma, Wash. (Curve 16d); and Western Larch at Sandpoint, Idaho; Cut in October, November and December.

TABLE 4.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR NORTHEASTERN WOODS.

Ref.No.	Species	Locality	Period of cutting	Form of tie	Form of pile	Number of ties
17b	Hemlock.............. (Unpeeled ties)	Escanaba, Mich	June, 1905 July, 1905	Hewn	7x7	100
17c	Hemlock.............. (Unpeeled ties)	Escanaba, Mich....	Aug., 1905 Sept., 1905	Hewn	7x7	100
17d	Hemlock.............. (Unpeeled ties)	Escanaba, Mich....	Oct., 1905 Nov., 1905	Hewn	7x7	100
18b	Hemlock..............	Escanaba, Mich....	June, 1905 July, 1905	Hewn	7x7	100*
18c	Hemlock..............	Escanaba, Mich....	Aug., 1905 Sept., 1905	Hewn	7x7	100†
18d	Hemlock..............	Escanaba, Mich....	Oct., 1905 Nov., 1905 Dec., 1905	Hewn	7x7	150‡
19c	Hemlock..............	Escanaba, Mich....	Aug., 1905 Sept., 1905	Hewn	7x2 8x1	200§
19d	Hemlock..............	Escanaba, Mich....	Oct., 1905 Nov., 1905 Dec., 1905	Hewn	7x2 8x1	200¶
20	Tamarack°............	Escanaba, Mich....	Winter, 1905-6	Hewn	7x7 8x1	100•
21	Tamarack♦............	Escanaba, Mich....	Winter, 1903-4	Hewn	7x2	33
22	Hemlock♦............	Escanaba, Mich.....	Winter, 1903-4	Hewn	7x2	67

* Average volume, 3.1 cubic feet.
† Average volume, 3.0 cubic feet.
‡ Average volume, 3.7 cubic feet.
§ Average volume, 3.0 cubic feet.
¶ Average volume, 3.5 cubic feet.
° Cut during winter and first weighed April 25.
• Average volume, 3.2 cubic feet.
♦ Piled one year with bark on, then peeled and re-piled.
Curves apply to second year's seasoning beginning May 15, 1905.

Figs. 16, 17 and 18 show the rate of seasoning for three groups of hemlock ties cut respectively in June and July, in August and September, and in October, November and December. The ties when green had a very high moisture content, and although they lost weight rapidly during the summer months, none of them reached a constant weight within the period of observation; those cut in June and July, the ones held longest, were still losing weight at the end of the second summer, 16 months from the time of cutting (Fig. 16, curve 18b).

Figs. 17 and 18 compare the rate of seasoning of ties openly piled (7x2 and 8x1) with those closely piled (7x7), and practically no difference occurred between these two conditions. As between the peeled and the unpeeled ties, however, considerable difference in the rate of seasoning is evident.

The curves in Fig. 20 are based on ties taken from stock which, having been closely piled with the bark on for a year, had then been

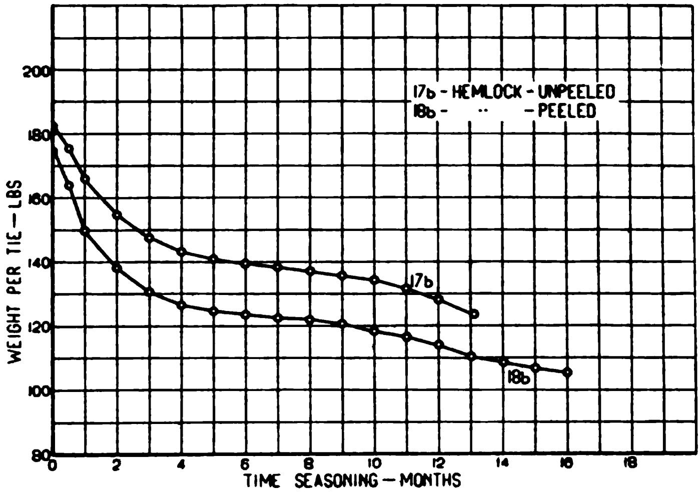


Fig. 16.—Seasoning of Hemlock Ties at Escanaba, Mich.; Cut in June and July.

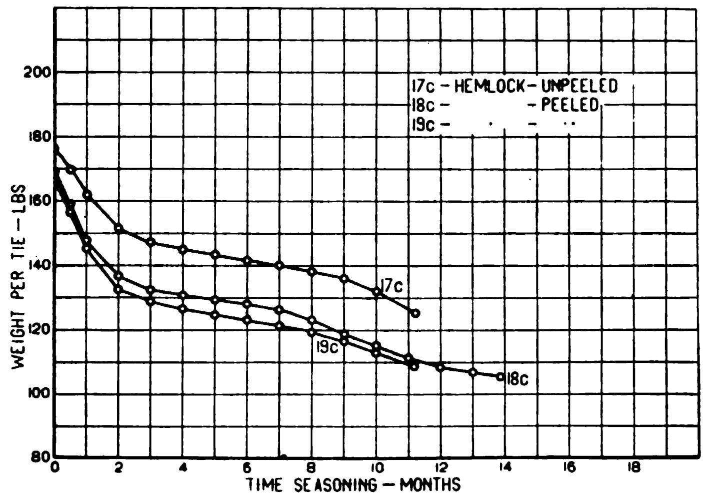


Fig. 17.—Seasoning of Hemlock Ties at Escanaba, Mich.; Cut in August and September.

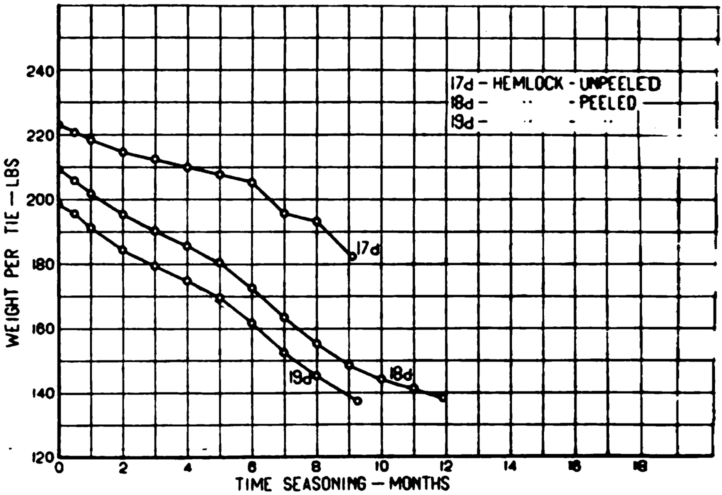


Fig. 18.—Seasoning of Hemlock Ties at Escanaba, Mich.; Cut in October, November and December.

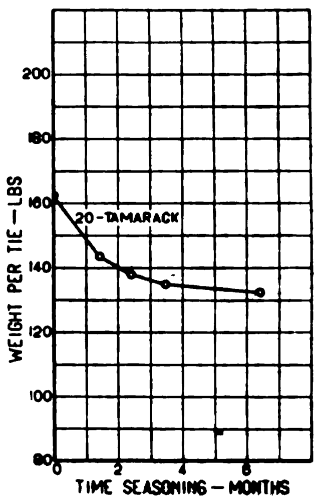


Fig. 19.—Seasoning of Tamarack Ties at Escanaba, Mich.; Cut in Winter

peeled and repiled in open forms. The curves give the losses which occurred after the first year. The final weight, 107.4 lbs. per tie for the hemlock, is equivalent to a weight of 30.6 lbs. per cu. ft., and the moisture content of 27.5 per cent., based on an average dry weight of 24 lbs. per cu. ft.* Freshly cut hemlock ties weighed from 55 to 57 lbs. per cu. ft.; they can readily be seasoned to 40 lbs. per cu. ft., a process which requires from four to nine months, according to the time of the year they are cut.

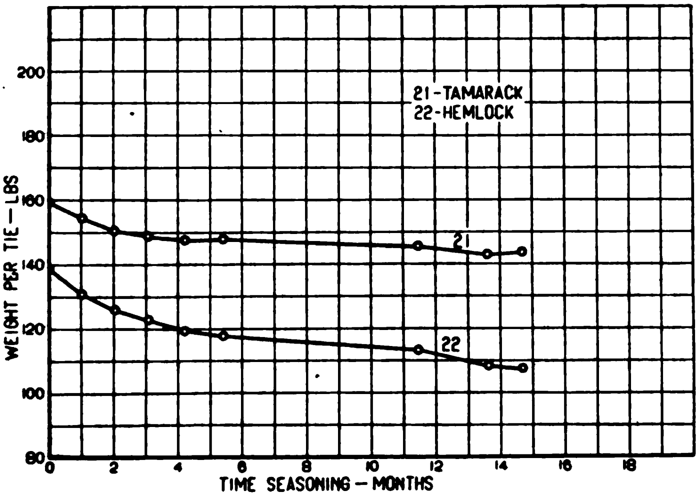


Fig. 20.—Seasoning of Hemlock and Tamarack Ties at Escanaba, Mich.; Old Ties Peeled and Repiled.

The tamarack ties, from which the curve in Fig. 19 was drawn, were cut during the winter and first weighed in late April. In six months they lost about 30 lbs. per tie and then weighed 41 lbs. per cu. ft. The prolonged seasoning shown in Fig. 20 resulted in a minimum weight of 39 lbs. per cu. ft., or a moisture content of 27.5 per cent. based on an oven-dry weight of 30.6 lbs. per cu. ft.*

SOUTHERN PINES.

Seasoning records were obtained on loblolly, longleaf and shortleaf pine at Silsbee, Tex., and on loblolly pine at Ackerman, Miss. The curves are shown in Figs. 21 to 25 and a list of the ties on which the curves are based is given in Table 5.

*The average of ten determinations on discs cut from the ties. See also footnote (2), page 193.

*The average of ten determinations on discs cut from the ties. See also footnote (2), page 193.

The influence of variations in meteorological conditions with the time of year is again well marked in the form of the curves, although conditions seem favorable to rapid drying throughout a large portion of the year.

TABLE 5.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR SOUTHERN PINES.

Ref. No.	Species	Locality	Period of cutting	Form of Tie	Form of pile	No. of Ties
23	Loblolly pine......	Silsbee, Texas.....	Jan., 1903	Hewn, 6'x8'x8'	6x2 7x2 8x2	300
23'	Loblolly pine......	Silsbee, Texas.....	Jan., 1904	Hewn, 6'x8'x8'	9x1	100
23a	Loblolly pine......	Silsbee, Texas.....	April, 1903	Hewn, 6'x8'x8'	7x2 8x2	300
23b	Loblolly pine......	Silsbee, Texas.....	July, 1903	Hewn, 6'x8'x8'	6x2 7x2	300
23c	Loblolly pine......	Silsbee, Texas.....	Sept., 1903 Oct., 1903	Hewn, 6'x8'x8'	7x2	200
23d	Loblolly pine......	Silsbee, Texas.....	Dec., 1903	Hewn, 6'x8'x8'	7x2	200
24	Shortleaf pine......	Silsbee, Texas.....	Feb., 1903	Hewn, 6'x8'x8'	6x2	200
24b	Shortleaf pine......	Silsbee, Texas.....	July, 1903	Hewn, 6'x8'x8'	6x2	100
24c	Shortleaf pine......	Silsbee, Texas.....	Aug., 1903	Hewn, 6'x8'x8'	2x2 9x1	300
25	Longleaf pine......	Silsbee, Texas.....	Jan., 1903	Hewn, 6'x8'x8'	6x2 7x2 8x2	300
25a	Longleaf pine......	Silsbee, Texas.....	April, 1903	Hewn, 6'x8'x8'	7x2 8x2	300
25b	Longleaf pine......	Silsbee, Texas.....	May, 1903	Hewn, 6'x8'x8'	6x2 7x2	150
26	Loblolly pine......	Ackerman, Miss...	Jan., 1905 Feb., 1905	Sawed, 6'x8'x8'	8x1 8x2	200
26a	Loblolly pine......	Ackerman, Miss...	April, 1904	Hewn, 6'x8'x8'	8x1 8x2	193
26b	Loblolly pine......	Ackerman, Miss...	May, 1904	Sawed, 6'x8'x8'	8x2	100
26b'	Loblolly pine.....	Ackerman, Miss...	June, 1904	Sawed, 6'x8'x8'	7x2 8x2	200
26c	Loblolly pine......	Ackerman, Miss...	July*, 1904 Aug., 1904 Oct.†, 1904	Sawed, 6'x8'x8'	7x2 8x2	400
26d	Loblolly pine......	Ackerman, Miss...	Nov., 1904 Dec., 1904	Sawed, 6'x8'x8'	7x1 7x2 8x1 8x2	250

*First weighed, July, 29.
†First weighed, October 3.

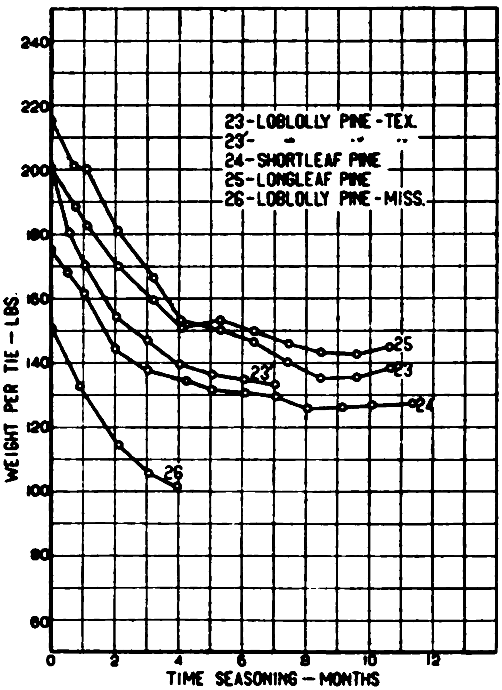


Fig. 21.—Seasoning of Ties at Silsbee, Texas, and Ackerman, Miss.; Cut in January and February.

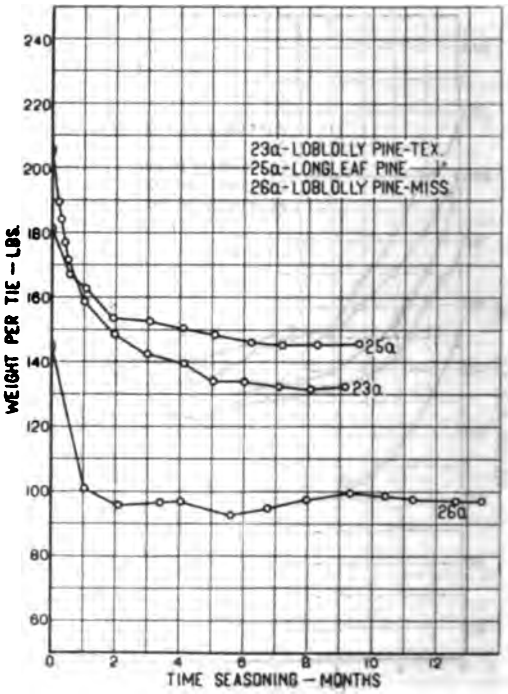


Fig. 22.—Seasoning of Ties at Silsbee, Texas, and Ackerman, Miss.: Cut in April.

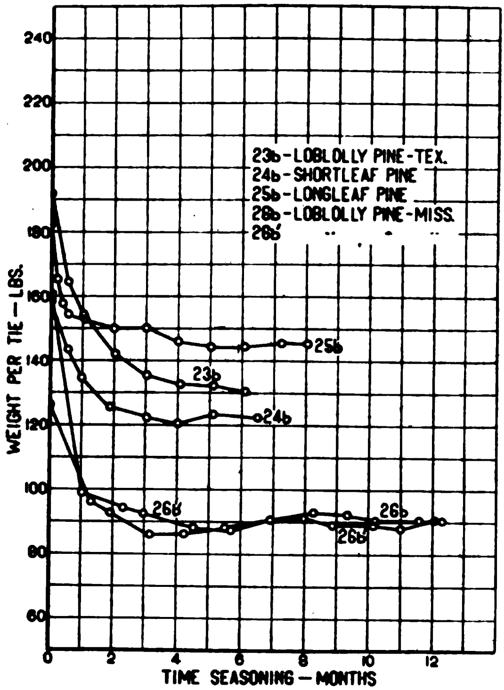


Fig. 23.—Seasoning of Ties at Silsbee, Texas, and Ackerman, Miss.; Cut in May, June and July.

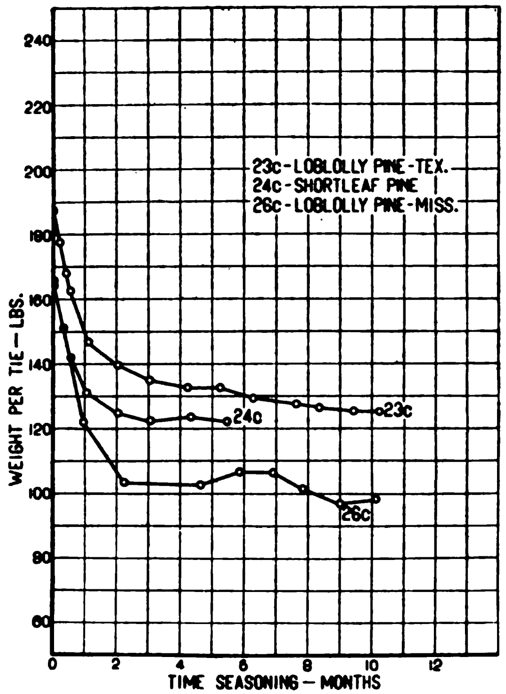


Fig. 24.—Seasoning of Ties at Silsbee, Texas, and Ackerman, Miss: Cut in August, September and October.

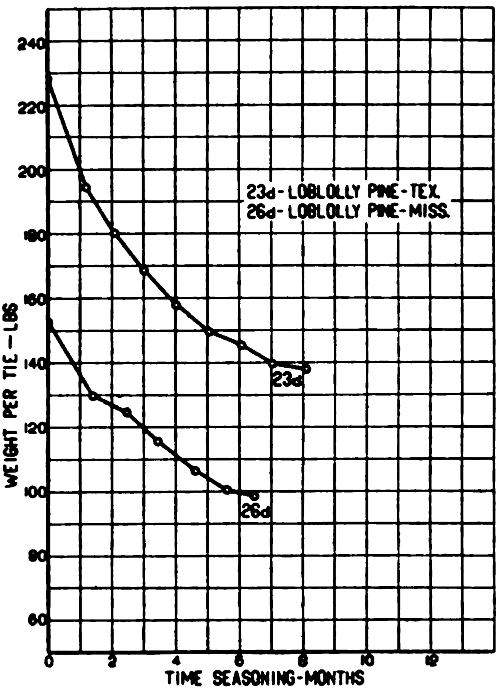


Fig. 25.—Seasoning of Ties at Silsbee, Texas, and Ackerman, Miss. Cut in November and December.

The ties cut in January and February are fairly dry at the end of 4 or 5 months, but continue losing appreciable weight for about 8 months. From April to October the seasoning is so rapid that there is comparatively little loss of weight after the first 2 or 3 months, even when the ties are held over until the following summer (see Fig. 24).

The curves for loblolly and shortleaf pines at Silsbee, Texas, resemble each other very closely; the longleaf pine dries a little more quickly, but the total weight lost is much less. The results of a few determinations of volume and air dry weight per cubic foot are given in Table 6. No data are available on which to base moisture calculation for these ties.*

TABLE 6.—VOLUME AND AIR-DRY WEIGHT PER CUBIC FOOT OF SAMPLE TIES—TEXAS.

Species	Time seasoned	No. of ties	Average volume	Weight per cu. ft. (air-dry)
	Years		Cu. ft.	Pounds
Loblolly pine	½ to 1½	15	3.4	37
Shortleaf pine	1½	6	3.0	39
Longleaf pine	½	9	3.3	42

The tests with loblolly pine at Silsbee, Tex., and Ackerman, Miss., were made in different years and therefore do not afford a good comparison of the effects of local differences in climate. Considering that the tests were made in different years, the two curves are surprisingly similar.

SOUTHERN HARDWOODS.

Seasoning records were obtained on red, white and bur oak, red gum and beech taken at points in Western Tennessee, Northeastern Arkansas, Southern Illinois and Southern Indiana. The rate of seasoning of these woods is shown by the curves in Figs. 26-30 and a description of the ties is given in Table 7.

The hardwoods in general differ from conifers in the slower rate at which they lose moisture and the longer time they require to become air dry. The tests of red oak in Arkansas cover a sufficient period to show very strikingly the slow rate of season of this wood. Ties cut in the spring and early summer (Fig. 27) were far from dry when they ceased to lose weight at the approach of winter; this is shown by the fact that during the following summer they lost nearly two-thirds as much moisture as during the first summer.

*Loblolly pine ties from Texas, tested at Lafayette, Ind., had an air dry weight of 38.4 lbs. per cu. ft., and contained then approximately 20 per cent. of moisture based on the oven dry weight. Forest Service Circular 39, page 27.

TABLE 7.—DESCRIPTION OF THE TIES ON WHICH ARE BASED THE SEASONING CURVES FOR SOUTHERN AND NORTHERN HARDWOODS.

Ref. No.	Species	Locality	Period of Cutting	Form of Tie	Form of Pile	No. of Ties
28	Red oak..	Portia and Black Rock, Ark	Jan., 1903 Feb., 1903 Mar., 1903	Hewn, 6"x8"x8'	7x2 8x2 7x7 9x2	1200
28a	Red oak..	Portia and Black Rock, Ark	Apr., 1903 May, 1903 June, 1903	Hewn, 6"x8"x8'	7x2 8x2 9x2	1200
28b	Red oak..	Portia and Black Rock, Ark	July, 1903	Hewn, 6"x8"x8'	7x2 8x2 9x2	400
28c	Red oak..	Portia and Black Rock, Ark	Aug., 1903 Sept., 1903	Hewn, 6"x8"x8'	7x2 8x2 9x2 8x9	800
28d	Red oak..	Portia and Black Rock, Ark	Oct., 1903 Nov., 1903 Dec., 1903	Hewn, 6"x8"x8'	8x2	1200
29	Red oak..	Trimble, Tenn............	Jan., 1905 Mar., 1905	Sawed and Hewn	7x2 8x1 8x2	300
29a	Red oak..	Trimble, Tenn............	June, 1904	Sawed and Hewn 6"x8"x8'	7x2 8x2	100
29c	Red oak..	Trimble, Tenn............	Aug., 1904 Sept., 1904	Sawed and Hewn 6"x8"x8'	7x2 8x2	400
29d	Red oak..	Trimble, Tenn............	Nov., 1904 Dec., 1904	Sawed and Hewn 6"x8"x8'	8x1 8x2	400
30	White oak	Enfield, Fairfield and Iuka, Ill.; Brownstown and Medora, Ind................	Jan., 1903	Hewn, 7"x8"x8.5'	7x2 7x7	381
30c	White oak	Enfield, Fairfield and Iuka, Ill.; Brownstown and Medora, Ind................	Aug., 1902	Hewn, *7"x8"x8'	8x7 8x8	95
30d	White oak	Enfield, Fairfield and Iuka, Ill.; Brownstown and Medora, Ind................	Oct., 1902	Hewn, *7"x8"x8'	6x2 6x4 8x2 8x8	232
31b	Bur oak...	Fairfield, Ill..............	July, †1903	Hewn, *7"x8"x8'	7x2 6x7	130
31c	Bur oak...	Fairfield, Ill..............	Sept., 1903	Hewn, *7"x8"x8'	8x2	50
32	Red gum..	Portia, Ark...............	Jan., 1903 Feb., 1903 Mar., 1903	Sawed, 6"x8"x8'	7x2 8x2	300
32a	Red gum..	Portia, Ark...............	Apr., 1903 May, 1903 June, 1903	Sawed, "6x8"x8'	7x2 7x7 8x2 9x2	300
32b	Red gum..	Portia, Ark...............	July, 1903	Sawed, 6"x8"x8'	8x2 9x2	100
32c	Red gum..	Portia, Ark...............	Aug., 1903 Sept., 1903	Sawed, 6"x8"x8'	8x2 Triangular	200

* Ties average smaller than nominal size.
† Late July and early August.

TABLE 7.—Continued

Ref. No.	Species	Locality	Period of Cutting	Form of Tie	Form of Pile	No. of Ties
32d	Red gum..	Portia, Ark...............	Oct., 1903 Nov., 1903 Dec., 1903	Sawed, 6'x8'x8'	8x2	300
33	Red gum..	Trimble, Tenn............	Jan., 1905 Feb.,‡1905 Mar., 1905	Hewn and Sawed	7x2 8x1 8x2	600
33a	Red gum..	Trimble, Tenn............	June, 1904	Sawed	7x2 8x2	200
33b	Red gum..	Trimble, Tenn............	July, 1904 Aug., 1904	Sawed	7x2 8x2	400
33d	Red gum..	Trimble, Tenn............	Oct., 1904 Nov., 1904 Dec., 1904	Hewn and Sawed	7x1 7x2 8x2	538
34	Beech.....	Trimble, Tenn............	Jan., 1905 Feb.,§1905 Mar., 1905	Sawed, 6'x8'x8'	7x1 7x2 8x1 8x2	400
34a	Beech.....	Trimble, Tenn............	June, 1904	Sawed, 6'x8'x8'	7x2 8x2	200
34c	Beech.....	Trimble, Tenn............	July,¶1904 Aug., 1904 Sept., 1904	Sawed	7x1 7x2 8x2	600
34d	Beech.....	Trimble, Tenn............	Nov., 1904 Dec., 1904	Sawed	7x1 7x2 8x1 8x2	400
35	Birch.....	McKeever, N. Y..........	||	Hewn	Various	1831
36	Maple.....	McKeever, N. Y..........	||	Hewn	Various	456
37	Beech.....	McKeever, N. Y..........	||	Hewn	Various	827

‡ First weights March 3–4, 1905.
§ First weights January 31, 1905.
¶ First weights August 3.
|| The first weights were obtained July, 1904; within a short time after the ties were cut from the log; the logs had been cut from 6 months to one year previously.

When the ties were cut in the winter and carried through two years the loss of weight during the second summer was nearly half that of the first summer (Fig. 26).

The records on white and bur oak cover too short a period to show very much about the seasoning of these species, but the structure of the wood suggests that they would season even more slowly than the red oak. The losses from the white and bur oak ties during the periods covered by the curves are small.

The curves for red gum in Arkansas are very similar to those for red oak in the same locality, but the gum shows a slightly greater total loss of weight and loses a greater proportion of the total during the early part of the drying period. The red gum in Tennessee shows very much

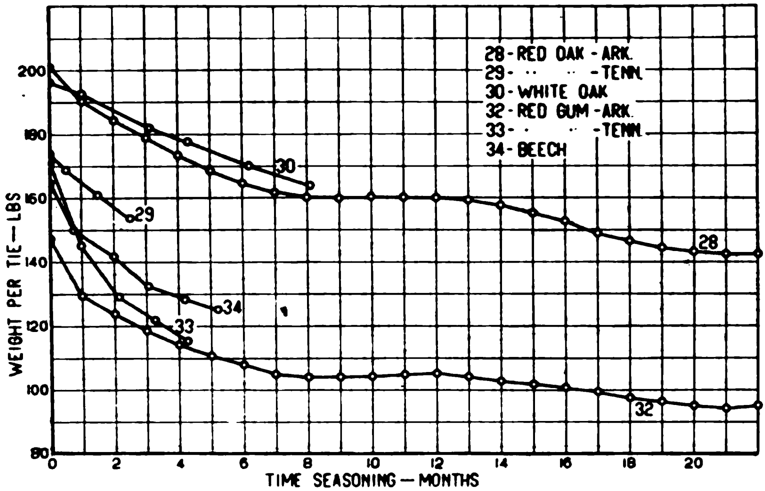


Fig. 26.—Seasoning of Hardwood Ties in Southern States; Cut in January, February and March.

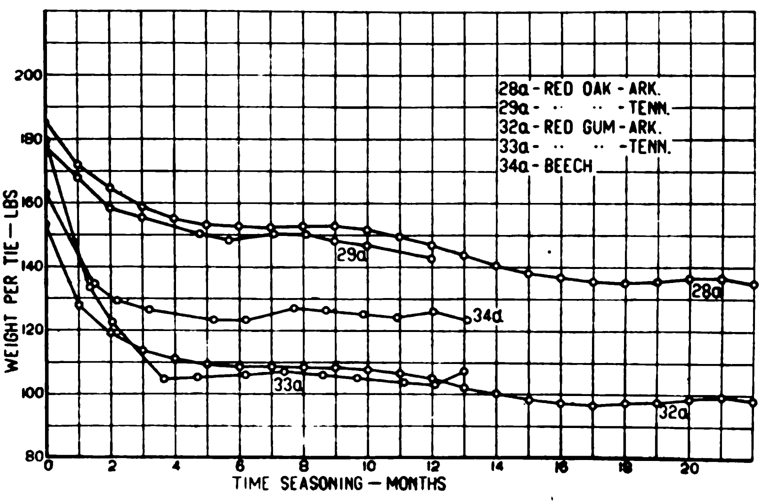


Fig. 27.—Seasoning of Hardwood Ties in Southern States; Cut in April, May and June.

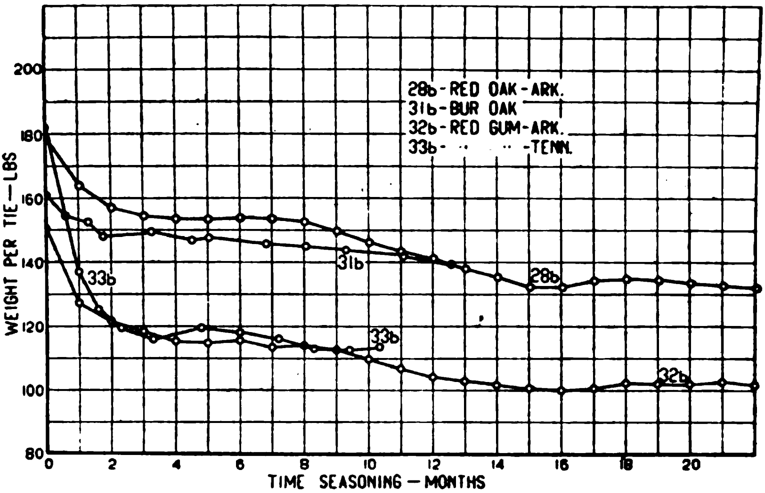


Fig. 28.—Seasoning of Hardwood Ties in Southern States; Cut in July.

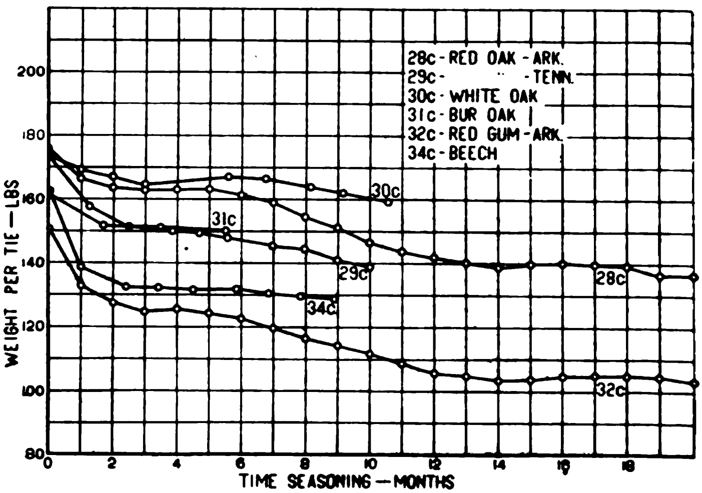


Fig. 29.—Seasoning of Hardwood Ties in Southern States; Cut in August and September.

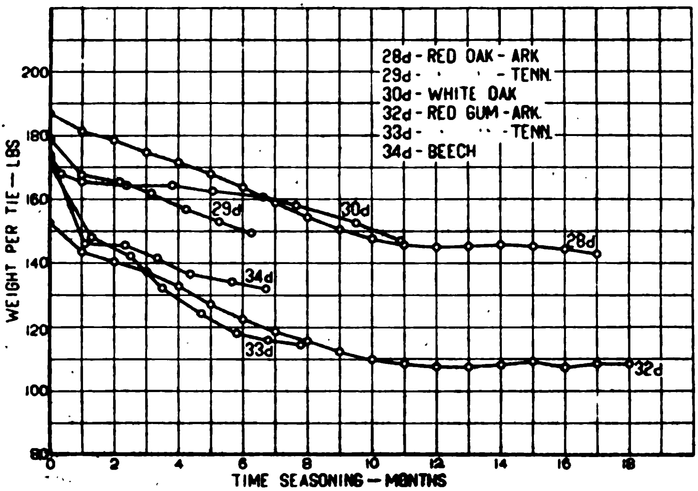


Fig. 30.—Seasoning of Hardwood Ties in Southern States; Cut in October, November and December.

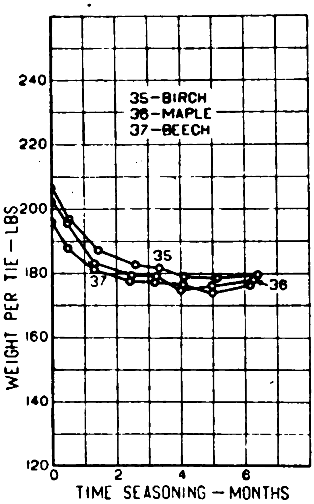


Fig. 31.—Seasoning of Birch, Maple and Beech Ties at McKeever, N. Y.

greater losses than that in Arkansas; the reason for this difference is not apparent, especially since the red oak curves for the two localities are similar.

Beech also shows a greater loss than red oak during the early stages of seasoning and falls between the Arkansas and Tennessee gums in this respect. Unfortunately, the tests on beech do not cover a period sufficient to show definitely how long is required for this species to become air dry, but the curves in Figs. 27 and 29 indicate that the loss of weight during the second summer would be relatively small.

NORTHERN HARDWOODS.

Data on the rate of seasoning hardwood ties in the North are very meager. The ties on which were based the curves shown in Fig. 31 were sawed in July from logs felled in the woods from six months to a year previously; the periods of seasoning indicated pertain, of course, to the ties after they were sawed. There was considerable loss of moisture from these ties during the first few months of seasoning, but values for the oven dry weight of these woods obtained from other sources* indicate a high moisture content—40 to 45 per cent.

POLES.†

Pole-seasoning tests were made by the Forest Service on chestnut in Maryland, New Jersey, North Carolina and Pennsylvania; on Southern white cedar in North Carolina; on Northern white cedar in Michigan; and on Western red cedar and Western yellow pine in California. In most cases the poles were cut at monthly intervals and the successive weights, showing the loss of moisture in each monthly lot, were averaged according to the four seasons of the year:‡

Spring cut—March, April and May.
Summer cut—June, July and August.
Autumn cut—September, October and November.
Winter cut—December, January and February.

The poles were seasoned in single tiers on skids which raised them one or two feet above the ground. A brief summary of the tests made is given below:

SOUTHERN WHITE CEDAR.

The curves for Southern white cedar shown in Fig. 32 are based on 50 poles cut each month from August, 1903, to July, 1904. The poles

*Determinations made by the Forest Service in connection with strength tests show an oven dry weight of 34 to 35 lbs. per cu. ft. for these species.

†All of the data on the seasoning of poles given in this Bulletin were included in slightly different form in Bulletin 84, "Preservative Treatment of Poles," but they are reprinted here to make the present publication more nearly complete.

‡The curves are plotted directly from tables as originally published and reprinted in Bulletin 84. In summarizing the data on ties cut in different months, the author found that five periods usually could be employed advantageously. However, it was not thought that the difference warranted the recalculation of all the pole seasoning tables.

were rafted about 90 miles down the Cape Fear River to Wilmington and were about 10 days on the trip. They were weighed after reaching Wilmington. Half of them were 30 feet and half 25 feet long; the average volume of the 30-foot poles was 20.76 cubic feet and of the 25-ft. poles 14.53 cu. ft. Based on an assumed oven dry weight of 20.7 lbs. per cu. ft.* The spring cut poles, which reached the lowest weight, contained 21 per cent. moisture after 10 months' seasoning.

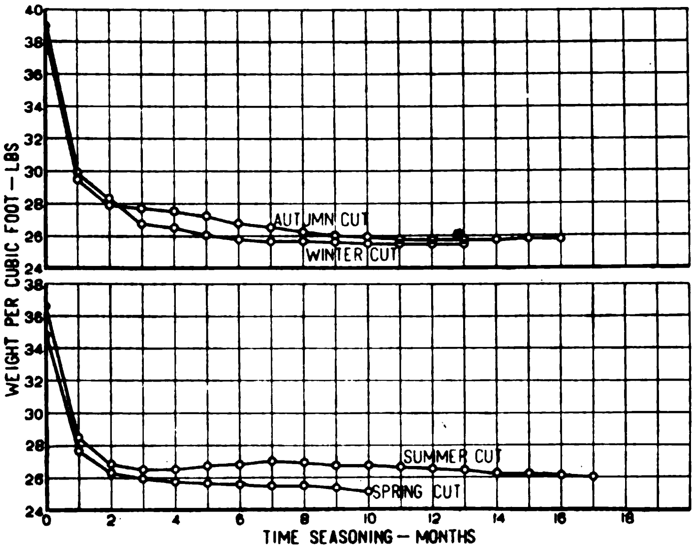


Fig. 32.—Seasoning of Southern White Cedar Poles at Wilmington, N. C.

NORTHERN WHITE CEDAR.

The seasoning curves for Northern white cedar shown in Fig. 33 are based on fifty 30-ft. poles cut each month from April to December, 1905. The poles were cut near Metropolitan, Mich., and seasoned on skids in the woods until February, 1906, when all were removed to the yard at Escanaba, Mich. The average volume of the poles was 17.62 cu. ft. The average dry weight of the wood, found from discs cut from the butts and tops of a number of poles, was 18 lbs. per cu. ft.† The lowest average moisture content reached by any group was 27 per cent. for the autumn cut poles.

WESTERN RED CEDAR.

The curves for Western red cedar poles (Fig. 34) are based on one hundred 40-ft. poles in each season's cut. The poles were cut near

*Average weight for species determined by Sharpless, Vol. IX, Tenth Census. This weight is based on the actual volume of the dry wood.

†Unless otherwise stated, the oven dry weights per cubic foot used in this Bulletin are based on the green volume of the wood.

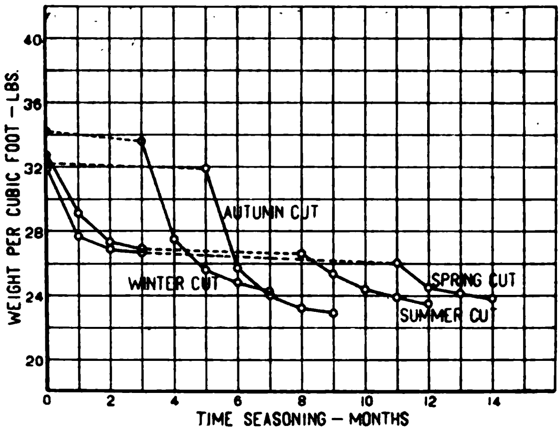


Fig. 33.—Seasoning of Northern White Cedar Poles at Escanaba, Mich.

Puget Sound, Wash., and transported by boats to San Pedro, Cal., where they were transferred to the storage yard. The first weights generally were taken in the yard from three to seven months after cutting, but there were 25 summer cut poles which were first weighed in the woods to obtain their green weight. The approximate dates of cutting and of first weighing were as follows:

Summer cut—Cut in July, 1906, and first weighed in January, 1907.

Autumn cut—Cut in October, 1906, and first weighed in May, 1907.

Winter cut—Cut in December, 1907, and first weighed in April, 1908.

Spring cut—Cut in May, 1908, and first weighed in July, 1908.

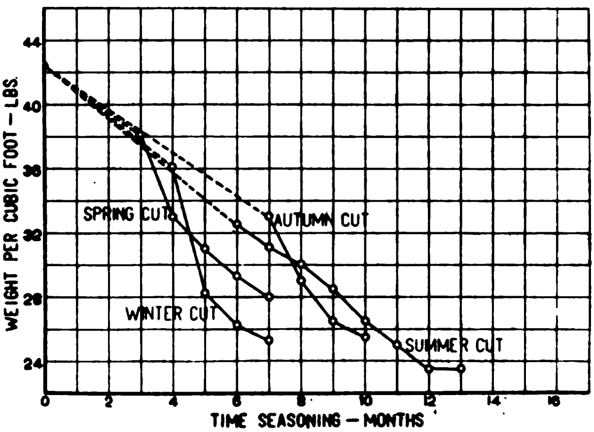


Fig. 34.—Seasoning of Western Red Cedar Poles at Wilmington, Cal.

The average volume, based on 300 poles for all four seasons, was 27.34 cu. ft. The oven dry weight of the wood, determined by sections cut from 12 poles, was 18.2 lbs. per cu. ft. The green wood, therefore, contained 133 per cent. water; while at their lowest weight, 23.5 lbs. per cu. ft., the summer cut poles contained 29 per cent. moisture.

WESTERN YELLOW PINE.

The curves showing the rate of seasoning for Western yellow pine (Fig. 35) are based on poles cut and seasoned near North Fork, Madera County, California, as follows:

Spring cut—100 poles, cut March, 1906.
Summer cut—100 poles, cut July, 1906.
Autumn cut—150 poles, cut October, 1906.
Winter cut—150 poles, cut January, 1907.

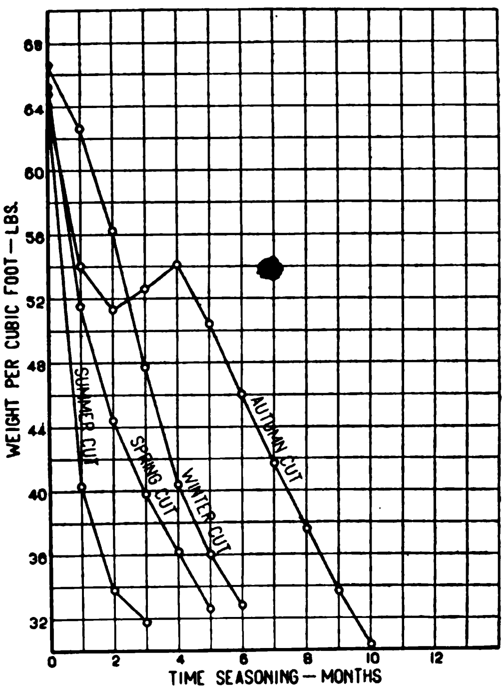


Fig. 35.—Seasoning of Western Yellow Pine Poles, Madera Co., Cal.

The poles were 40 ft. long, and their average volume was 26.1 cu. ft. Their oven dry weight, determined from sections cut from a number

of the poles, was 26.2 lbs. per cu. ft. The green poles contained on an average nearly 150 per cent. moisture. The autumn cut poles, which after 10 months' seasoning were reduced to 30.3 lbs. per cu. ft., then contained 15.6 per cent. moisture.

CHESTNUT.

Thorndale and Paoli, Pa.—The chestnut poles for the Thorndale and Paoli curves (Fig. 36) were cut monthly in lots of 50 from June, 1903, to May, 1904, inclusive. The average volume of all the poles was 20 cu. ft., except that of the summer cut poles, which was 21 cu. ft.

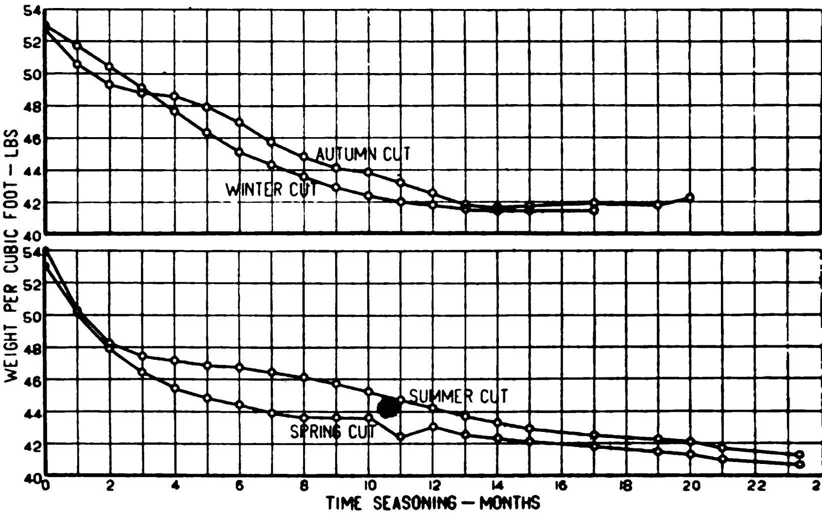


Fig. 36.—Seasoning of Chestnut Poles at Thorndale, Pa.

Dover, N. J.—The seasoning curves for chestnut poles in the vicinity of Dover, N. J. (Fig. 37), are based on fifty 30-ft. poles cut each month from August, 1902, to May, 1903, inclusive, except the months of November and February. The average volume of the poles was 22 cu. ft.

Pisgah, N. C.—The Pisgah curves (Fig. 38) are based on fifty chestnut poles cut monthly from June, 1903, to May, 1904. One-half of these were 30 ft. and the other half 25 ft. long. The location is on the north slope of Mount Pisgah at an elevation of 4,500 ft. The average volume of the 30-ft. poles was 21.12 cu. ft. and of the 25-ft. poles, 14.7 cu. ft.

Parkton, Md.—The curves for the poles seasoned in the vicinity of Parkton (Fig. 39) are based on fifty 30-ft. poles cut monthly from September, 1905, to July, 1906. The average volume of these poles was 20 cu. ft.

The poles seasoned at Parkton, Md., had an average oven dry weight of 30.4 lbs. per cu. ft., as determined from discs cut from about a dozen poles. The average moisture content of the autumn cut poles which

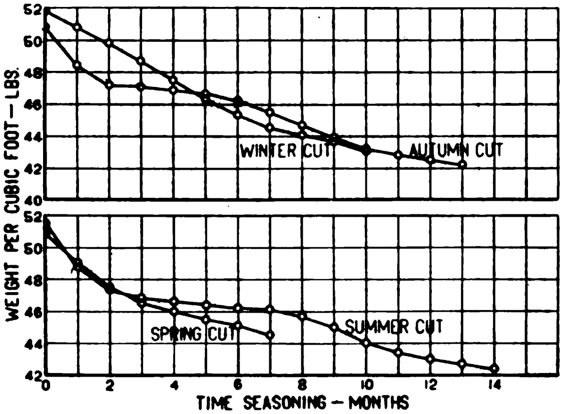


Fig. 37.—Seasoning of Chestnut Poles at Dover, N. J.

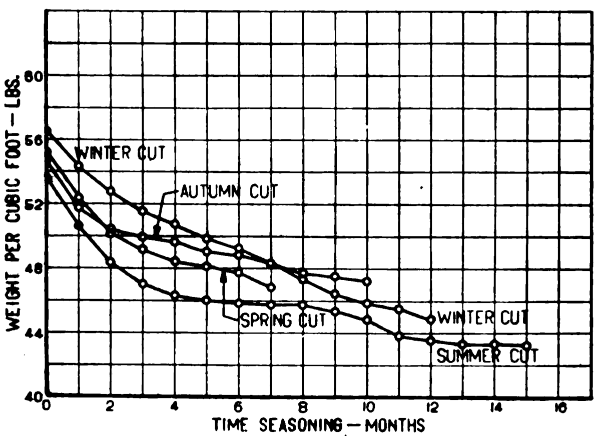


Fig. 38.—Seasoning of Chestnut Poles at Pisgah, N. C.

seasoned longest was 48 per cent. when last weighed, 12 months after cutting. If the same dry weight be assumed for the poles cut at Thorn-

dale, Pa., the moisture content after practically two years' seasoning would be about 34 per cent.*

COMPARISON OF SPECIES.

Conifers, under favorable conditions, season rapidly; that is, in from 3 to 6 months, as shown by the spring and summer cuts of Southern white cedar and the winter, spring and summer cuts of Western yellow pine. Under less favorable conditions, from 8 months to a year is required, as in the case of fall cut Southern white cedar, of fall cut Western yellow pine, and of spring, summer and fall cut Northern white cedar. Western red cedar, handled as in these tests, falls also in this class, provided the seasoning period be computed from the time of cutting.

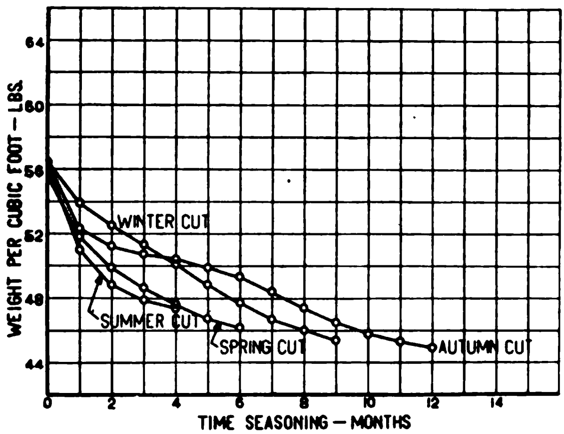


Fig. 39.—Seasoning of Chestnut Poles at Parkton, Md.

A very great loss took place in the weight of the Western yellow pine poles—about 33 lbs. per cu. ft., or more than 800 lbs. per pole. While these poles were still losing rapidly when the last weighings were made, the moisture content, based on an average dry weight, was fairly low (15 to 25 per cent.) and doubtless the rate of loss would have suddenly halted had the weighings been continued. Sharp breaks would then have occurred in the curves at a weight of about 30 lbs. per cu. ft.

The chestnut poles season slowly when compared to the coniferous woods. At Thorndale, Pa., where the weighings were continued longest, spring and summer cut poles held for two years were still losing weight at the end of the test. At this time they weighed 40.7 and 41.3 lbs.

*No oven dry weight determinations were made on the chestnut poles cut in Pennsylvania, New Jersey or North Carolina. The moisture calculations given in Bulletin 84 for these poles are based on the dry weight of 28.07 lbs. per cu. ft. given by Sharpless in Vol. IX, Tenth Census.

per cu. ft., and contained 34 and 36 per cent. moisture based on an assumed oven dry weight of 30.4 lbs. per cu. ft.* At Parkton, Md., the spring cut poles reached a weight of 46 lbs. per cu. ft. in 6 months, while the winter and autumn cuts reached the same weight in 8 and 10 months, respectively. While such poles could hardly be considered air dry, in most cases longer periods of seasoning probably would not be warranted in commercial operations.

CROSS-ARMS.

Seasoning records were obtained at Norfolk, Va., on loblolly pine cross-arms, shipped from Montgomery County, North Carolina. The

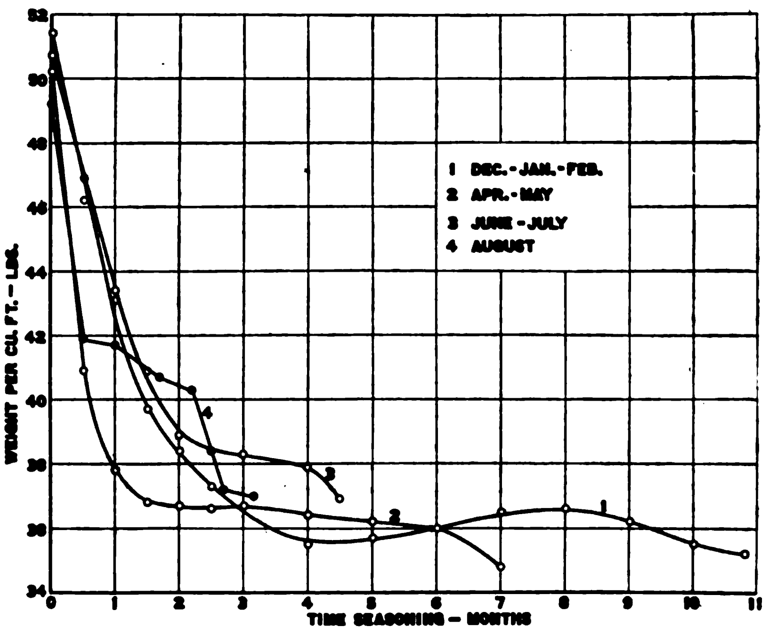


Fig. 40.—Seasoning of Loblolly Pine Cross-Arms at Norfolk, Va. (Intermediate Grade).

arms, 3¼x4¼ in. by 10 ft., were graded into three classes: heartwood, sapwood and intermediate. The seasoning rate for arms of the intermediate class, cut monthly from December, 1905, to August, 1906, March excepted, is shown in Fig. 40. These arms were stacked 20 in a tier with the outer and middle arms of each tier set on edge (see Fig. 52)

*See page 196.

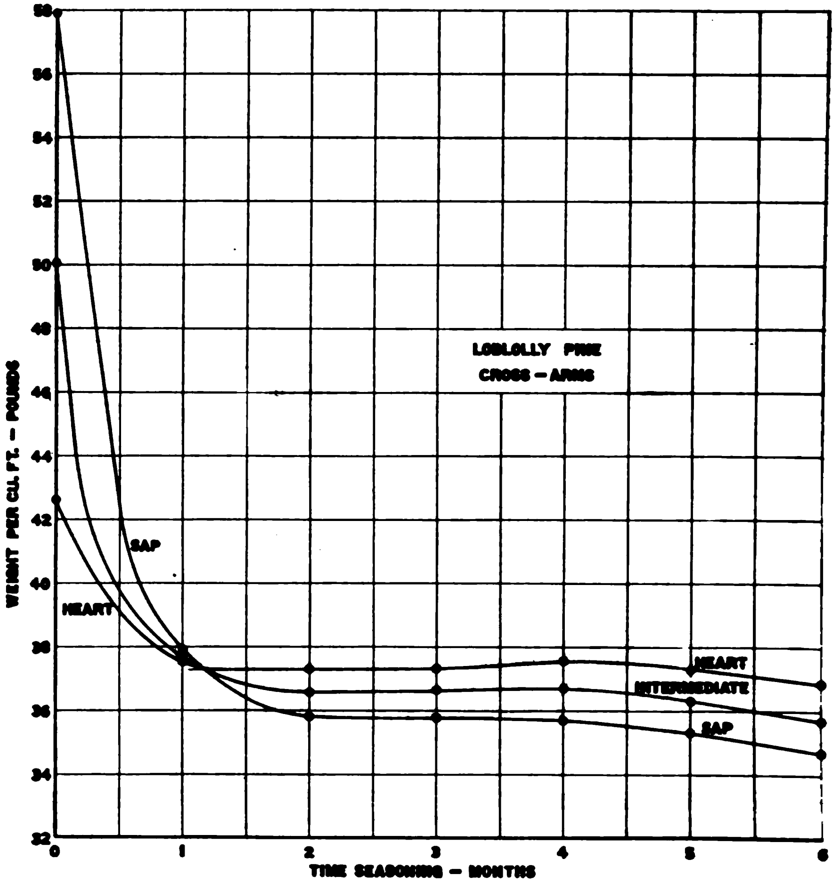


Fig. 41.—Comparative Seasoning of Sapwood, Heartwood and Intermediate Loblolly Pine Cross-Arms at Norfolk, Va.

TABLE 8.—DESCRIPTION OF TIMBERS ON WHICH ARE BASED THE SEASONING CURVES IN FIGURES 41 TO 46.

Species	Locality in which cut	Place where seasoned	No. of pieces weighed‖	Date of first weights	Size	How piled	Moisture content*	
							Green	Dry
Douglas fir	Lane Co., Oreg	Eugene, Oreg	10	June-July, 1906	8"x16"x16'	....	....	....
Douglas fir	Lane Co., Oreg	Eugene, Oreg	10	May, 1907	5"x 8"x16'	....	32.2	11.3
Douglas fir	Lane Co., Oreg	Eugene, Oreg	20	July, 1907	5"x 8"x16'	....	30.6	12.7
Tamarack†	St. Louis Co., Minn	Lafayette, Ind	5	Feb., 1906	4"x10"x16'	Enclosed shed	44.0	14.4
Tamarack†	St. Louis Co., Minn	Lafayette, Ind	5	Feb., 1906	6"x12"x16'	Enclosed shed	60.0	23.0
Norway pine†	St. Louis Co., Minn	Lafayette, Ind	5	Feb., 1906	4"x10"x16'	Enclosed shed	35.6	13.7
Norway pine†	St. Louis Co., Minn	Lafayette, Ind	5	Feb., 1906	6"x12"x16'	Enclosed shed	42.9	16.7
Shortleaf pine†	Arkansas	Lafayette, Ind	6	July 15, 1907	8"x12"x16'	Enclosed shed	48.0	15.2
Shortleaf pine†	Arkansas	Lafayette, Ind	6	July 15, 1907	5"x 8"x16'	Enclosed shed	45.6	11.5
Redwood	Albion, Cal	Berkeley, Cal	3	April, 1908‡	8"x16"x16'	Enclosed shed	68.0§	19.6
Redwood	Albion, Cal	Berkeley, Cal	3	April, 1908‡	7"x 9"x16'	Enclosed shed	85.7§	16.6
Redwood	Albion, Cal	Berkeley, Cal	3	April, 1908‡	3"x14"x16'	Enclosed shed	104§	13.7
Redwood	Albion, Cal	Berkeley, Cal	3	April, 1908‡	2" x8"x16'	Enclosed shed	89.7§	13.0
Western hemlock	Grays Harbor and Buckley, Wash	Seattle, Wash	6	July 7, 1906	8"x16"x16'	Open shed	41.9	18.5
Western larch	Stevens Co., Wash	Seattle, Wash	3	Nov. 29, 1907	8"x16"x16'	Open shed	47.8¶	17.7¶
Western larch	Stevens Co., Wash	Seattle, Wash	3	Nov. 29, 1907	8"x12"x16'	Open shed	55.0	18.5
Western larch	Stevens Co., Wash	Seattle, Wash	3	Nov. 16, 1907	5"x 8"x16'	Open shed	45.7	16.9

*The moisture content of these timbers was computed from the weights of the beams and the moisture in a section cut from them after they were tested for strength.

†Weights per cubic foot based on air-dry volume (green volume used for other species).

‡The timbers were kept moist by sprinkling for four months after they were first weighed, and practically no loss of weight occurred except in the 2 in. x 8 in. size.

§Moisture content based on second weight shown in curves (Fig. 44).

¶Average of two beams only.

to allow free circulation of air. The number of arms on which each curve is based is as follows:

December	246
January	340
February	250
April	230
May	380
June	209
July	256
August	95

The green weight of the arms ranged from 49 to 52 lbs. per cu. ft.,* but during the testing period they seasoned to a weight of 35 to 37 lbs. per cu. ft. On an average oven dry weight of 28.1 lbs. per cu. ft., a weight of 50 lbs. (wood and water) represents 80 per cent. moisture, and a weight of 35 lbs. per cu. ft., 26 per cent. moisture.

Fig. 41 shows for arms cut in the spring months the average losses from the heartwood, sapwood and intermediate grades. While the green heartwood arms weighed 42.6 lbs. per cu. ft., the intermediate grade 50.3 lbs. and the sapwood grades 57.9 lbs., all had seasoned to the same weight in a little over one month's time. By further seasoning the relative position of the sapwood and heartwood arms was reversed, the sapwood becoming considerably drier than the heartwood.

SAWED TIMBERS.

The joists, car sills and stringers on which seasoning records were obtained are here grouped, for convenience, as one class. These timbers were obtained for strength tests and, as a rule, were selected at mills and lumber yards. While precautions were taken to have the material reach the testing laboratories sufficiently green to prevent the strength being affected by drying,† still some moisture was lost before the first weights were taken. The data for the seasoning curves shown in Figs. 42 to 46 were obtained on certain of the timbers which were set aside to be tested in air dry condition. A brief description of the material, together with the average moisture content of the timbers when first weighed and when air dry, is given in Table 8.

The several species on which data are available show considerable variation in their rate of seasoning. For example, redwood, in the 7-in. x 9-in. and 8-in. x 16-in. sizes, lost weight constantly for 3 years and then contained, respectively, 17 and 20 per cent. moisture, while 8-in. x 12-in. shortleaf pine contained 15 per cent. moisture after 15 months' seasoning, and 6-in. x 12-in. Norway pine contained 17 per cent. after 8½ months. In comparing these species differences in climate and in

*The average volume was 0.91 cu. ft.

†See Forest Service Bulletin 70, "Effect of Moisture on the Strength and Stiffness of Wood," by Harry Donald Tiemann; and Circular 108, "The Strength of Wood as Influenced by Moisture," by the same author.

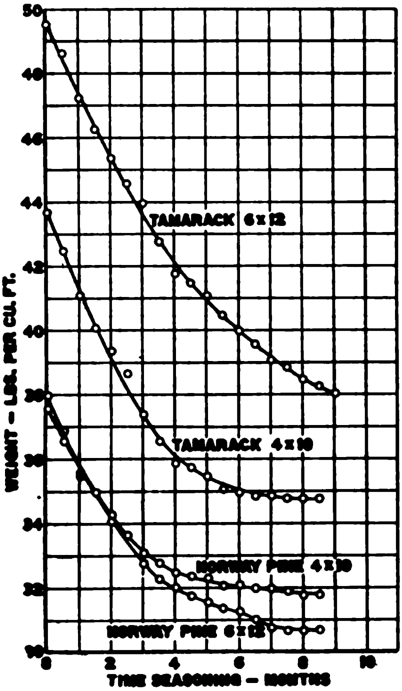


Fig. 42.—Seasoning of Norway Pine and Tamarack Timbers.

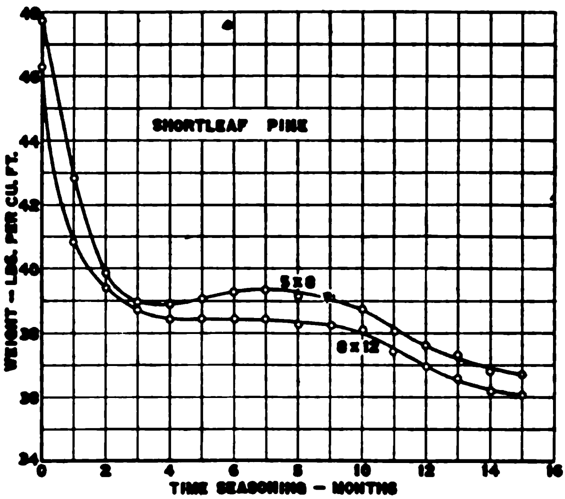


Fig. 43.—Seasoning of Shortleaf Pine Timbers.

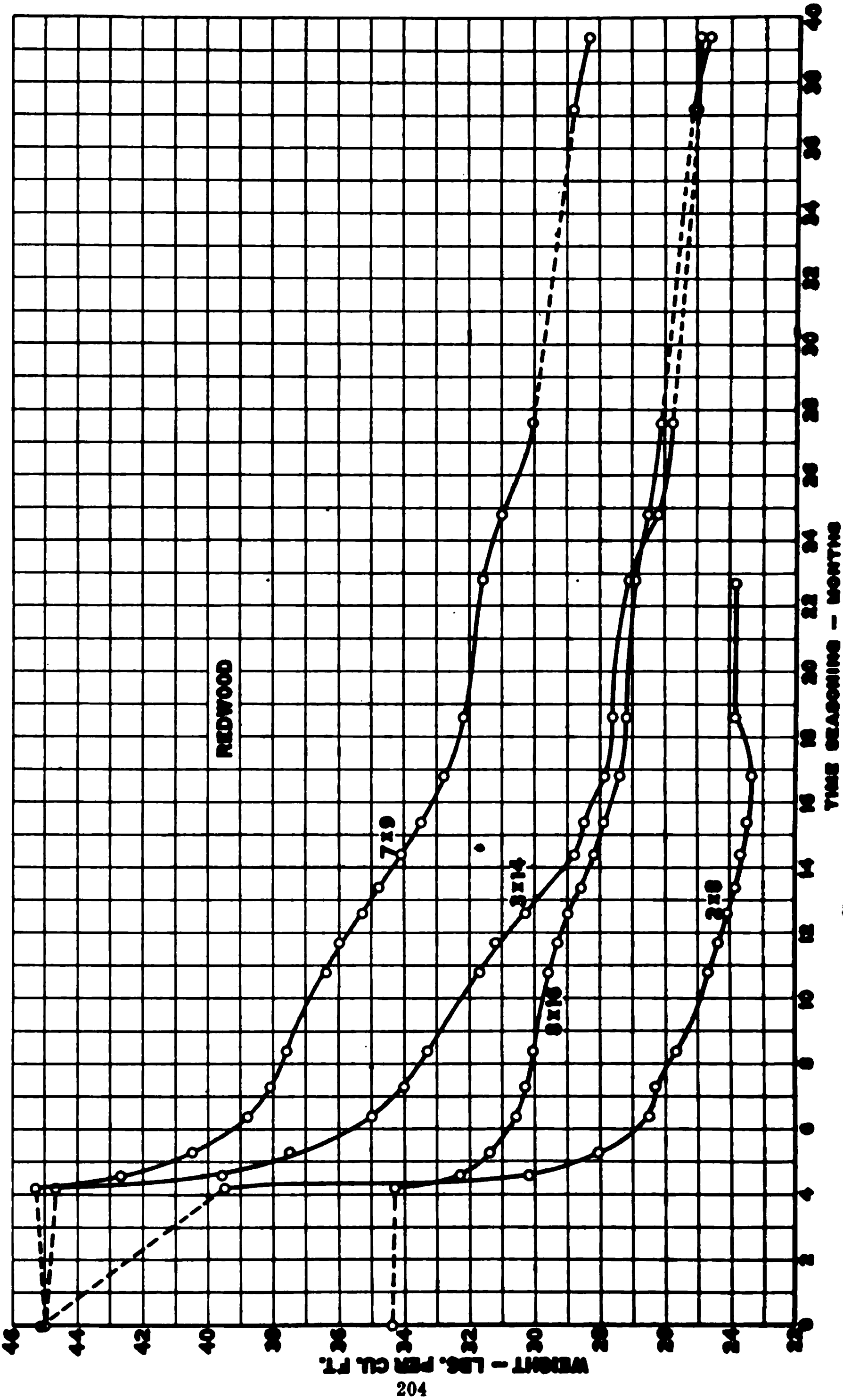


Fig. 44 — Seasoning of Redwood Timbers

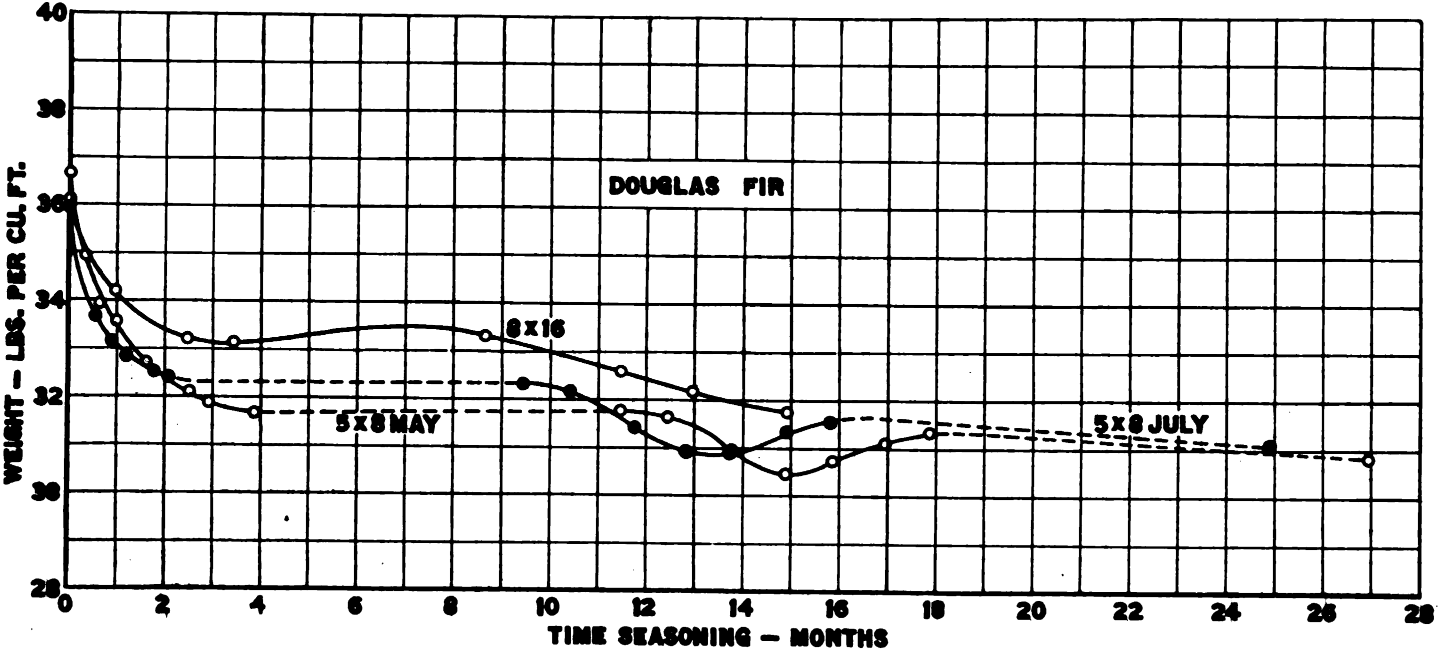


Fig. 45.—Seasoning of Douglas Fir Timbers.

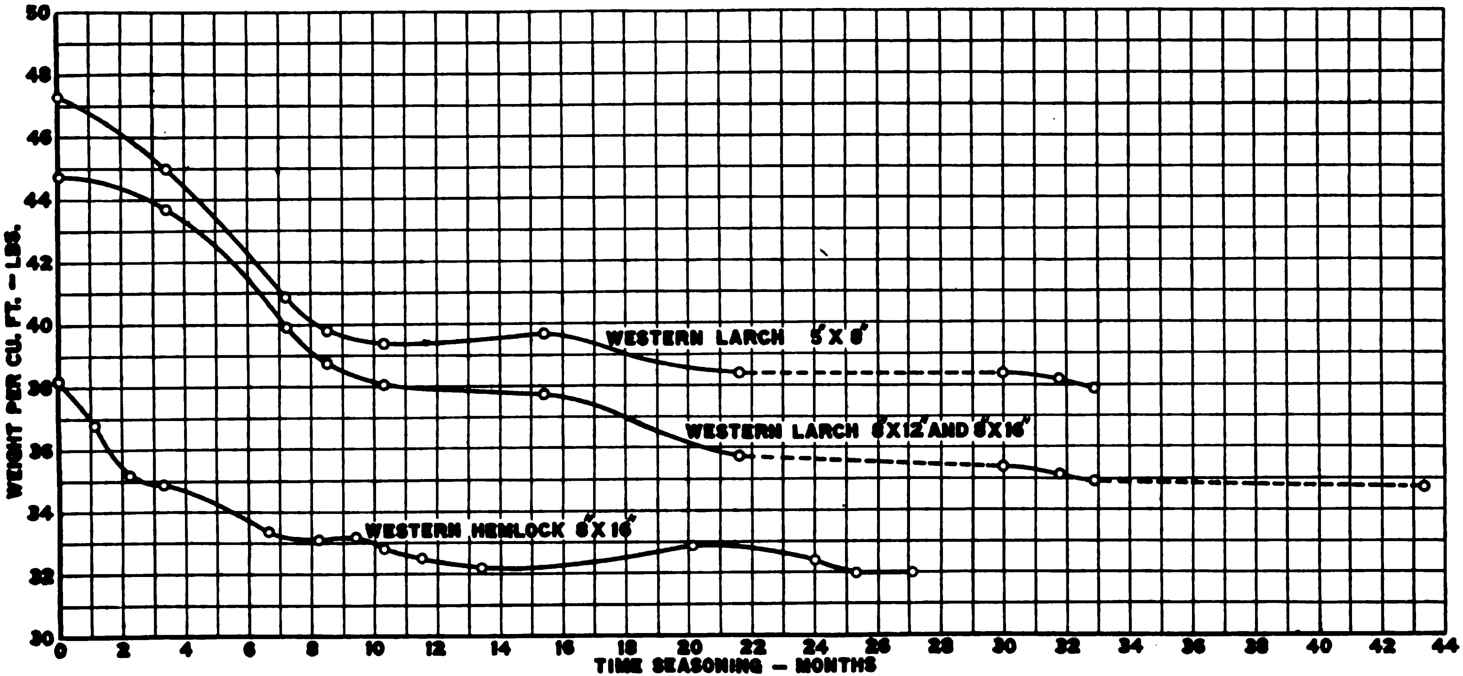


Fig. 46.—Seasoning of Western Hemlock and Western Larch Timbers.

other conditions must, of course, be taken into account, and it must be remembered that the smaller pieces dry somewhat more rapidly than the larger ones.

FACTORS WHICH INFLUENCE THE RATE OF SEASONING.

CLIMATIC AND METEOROLOGICAL CONDITIONS.

The accelerating effect of warm, dry weather on the rate of evaporation and the retarding effect of cold or wet weather were seen very plainly in those seasoning tests which were started at different times of the year, and also in tests where the weighings were continued from one summer through the winter into the succeeding summer. Timbers which had become fairly dry ceased to lose moisture, or even gained weight, during the wet or the cold, damp weather. But timbers cut in the unfavorable periods showed a moisture loss during subsequent unfavorable weather, and by the time of the warm, dry weather they had so far seasoned that the rate of loss was fairly constant throughout both periods.

The effect of climatic variations in the different places where the tests were made was less on the whole than the effect of the changes in a given locality throughout the year. Each locality had its favorable and its unfavorable periods. Although direct comparisons of climatic effects cannot be made because different species were studied in the different localities, the effect of hot, dry and long summers can be seen plainly in some of the curves. The curves for the New Mexico ties (Figs. 1 to 10) exemplify very rapid seasoning; those for Northern Michigan (Figs. 16 to 20 and 33) exemplify short summers and slow seasoning.

By considering the effect of the time of year on rate of seasoning, timber may be cut at such time as to obtain either slow or rapid drying. When timber is cut in one part of the country to use in another part, climatic conditions should also be taken into account. Thus in the case of a timber-treating plant drawing supplies from different parts of the country, it would be worth while to consider whether the timber should be held for seasoning at the plant or in the locality where cut.

SPECIES AND FORM OF TIMBER.

Variations in the rate of seasoning among species may be due to differences either in moisture content or in permeability of the wood. Of two pieces of wood differing in moisture content, other conditions being equal, the one with most moisture will dry the more rapidly, and in a comparatively short time both pieces will reach about the same condition. This rule does not apply strictly between different species, even when of similar structure, and in pieces of the same size and form, but with conifers the usual variation between the species does not seem sufficient to necessitate separate treatment.

Sapwood of the conifers contains, as a rule, very much more moisture than does the heartwood, and a difference in the proportion of heartwood and sapwood in two timbers of the same species accounts for a large part of the difference in moisture content. But sapwood loses moisture more rapidly than the heartwood, and this tends to equalize the time required for the two pieces to become air dry. This fact is shown strikingly in the case of loblolly pine cross-arms of the heart, sap and intermediate grades (Fig. 41). Although these three classes varied from 51.5 to 105.8 per cent. in their average green moisture content, all grades were in practically the same condition five weeks after seasoning began. Furthermore, so far as the data presented afford a basis for comparison, ties of different coniferous species, all seasoned under the same conditions, differed usually much less in time required to become air dry than in amount of moisture lost. As examples of this, we may compare Douglas fir and "red" or "black" pine in New Mexico (Figs. 1 to 9 and especially Fig. 5); or else longleaf, shortleaf and loblolly pine in Texas (Figs. 21 to 24). This rule is not true in all cases, however; tamarack from Northern Michigan, cut in winter, reached an almost constant weight in 8 months (4 months after favorable seasoning weather set in), but hemlock, cut in the late fall, was still losing weight after 10 and 12 months' seasoning. Between the conifers and certain of the hardwoods the difference in the time required for seasoning is very great and the hardwoods also vary much among themselves. Chestnut and the oaks give up moisture slowly, while beech, birch, and maple season somewhat more rapidly. But there is very little information on the rate of seasoning of these species.

The size of the piece influences the time required for seasoning, because it affects the relation of the volume of a timber to its surface area and the distance which the moisture on the interior must traverse to escape from the surface. This influence, however, is not as great as might be expected. Shortleaf pine, 5-in. x 8-in. beams, contained only 3 per cent. less moisture after 15 months' seasoning than the 8-in. x 12-in. size; redwood, 7-in. x 9-in. timbers, contained 3 per cent. less after 3 years than the 8-in. x 16-in. size, and the 3-in. x 14-in. size contained 3 per cent. less than the 7-in. x 9-in. Because of the great variations in the initial moisture content, not much can be learned by comparing the various sizes of redwood during the earlier stages of seasoning. In case of the shortleaf pine the 5-in. x 8-in. and 8-in. x 12-in. sizes had approximately the same initial moisture content, and the difference in the rate of loss during the early stages is evident; the beams were seasoned for 15 months and at the end of 60 days those of the larger size had lost 67 per cent. of their total loss, while those of the smaller size had lost 71 per cent. of this amount.

A very good example of the effect of size is afforded by the Western larch. Beams 5 in. x 8 in. in size which were held 33 months seasoned from 45.7 per cent. moisture to 16.9 per cent.; beams 8 in. x 16 in. seasoned during the same period from 47.8 per cent. to 18.5 per cent. mois-

ture. In the 5-in. x 8-in. size 85 per cent. of the total moisture loss occurred during the first 10 months, while in the 8-in. x 16-in. size only 71 per cent. occurred in this time.

MANNER OF EXPOSURE.

The extent to which timber is exposed to atmospheric influence has an important bearing on the evaporation of moisture from its surface. The exposure is affected chiefly by the manner of piling the timber. In many of the tie-seasoning tests various forms of piles were used, and

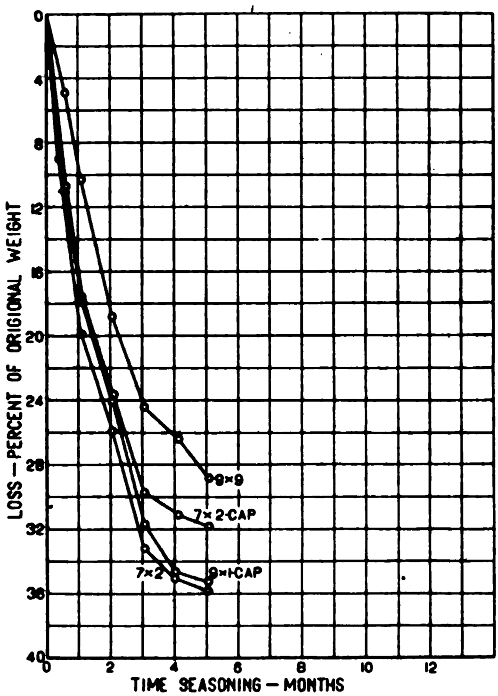


Fig. 47.—Comparative Seasoning of 9x9, 9x1 and 7x2 Piles. (Loblolly Pine Ties, Silsbee, Texas; Cut in March.)

it was found that the influence of the pile form on the rate of seasoning was very slight. However, these tests were made on isolated piles, usually of 50 ties each. If weather conditions are favorable isolated piles permit rapid seasoning, however closely the ties are stacked, but if the piles themselves are crowded together the influence of the form of pile undoubtedly becomes more pronounced. Even in the small isolated piles more difference was apparent. Figs. 47 and 48 indicate that the more open piles season more rapidly, although some of the differences shown

are due to differences in the initial moisture content of the ties. The curves are based on loblolly pine ties seasoned at Silsbee, Tex.

The combined effect on the rate of seasoning of close piling of ties and retention of their bark is indicated by tests made on hemlock at Escanaba, Mich. Ties that had been in the yard,* piled solidly with the bark on, in accordance with the usual practice at that time, weighed 40 lbs. per cu. ft. at the end of one year. (See Fig. 20 and Table 3). The average weight of peeled hemlock ties in various isolated piles seasoned

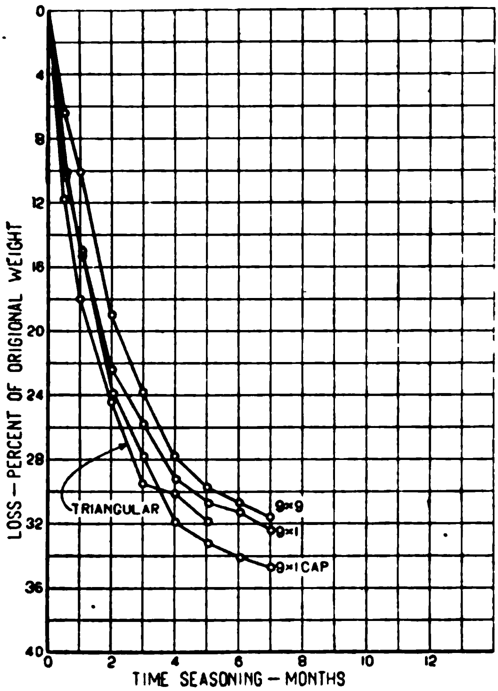


Fig. 48.—Comparative Seasoning of 9x9, 9x1 and Triangular Piles. (Loblolly Pine Ties, Silsbee, Texas; Cut in January.)

for one year ranged from 36 to 38 lbs. per cu. ft., and was usually between 36 and 37 lbs.

The effect of the form of pile was shown more strikingly, as well as more accurately, in the cross-arm tests. Ten-foot arms of the sapwood class, cut in July and piled openly with 20 arms in each tier, contained 30 per cent. moisture after 60 days' seasoning. (Fig. 49). Other arms, similarly piled, except that 28 arms were placed in each tier, contained 50 per cent. moisture after the same period. After a little more

*The tie yard of the Chicago & Northwestern Railway Company's wood-preserving plant.

than 4 months the first lot contained 20 per cent. moisture, while the condition of the second lot corresponded to that of the first lot after 2 months' seasoning. Even the closer of these two sets of piles permitted considerable air circulation (Figs. 50 and 51). Had the arms in the one pile been stacked solidly, as is frequently done in commercial practice, the difference in the rate of seasoning would have been still greater.

Attempts to determine the effect of the position of piles with regard to wind direction showed negligible results. On this point it should be

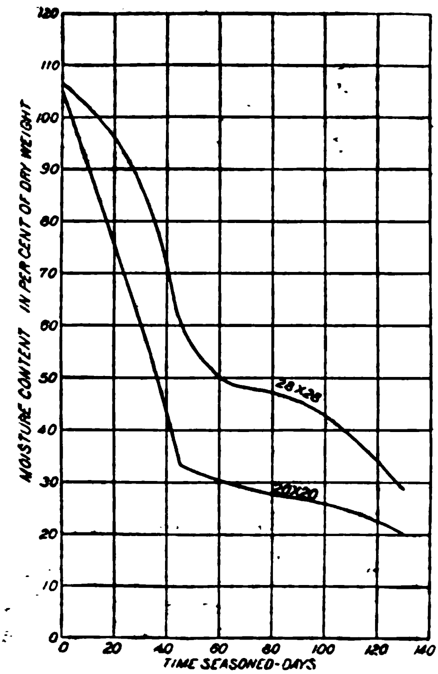


Fig. 49.—Comparative Seasoning of Loblolly Pine Cross-Arms, Piled 28x28 and 20x20.

recalled that the conditions of exposure in the case of the single pile show far greater variation than in the case of an assemblage of piles in a crowded timber yard.

Site, too, has an important effect on seasoning. Chestnut poles in Maryland which were fully exposed to sun and wind lost 25 lbs. per pole more in 10 months than others partly protected by a hill and surrounding trees; and poles skidded over dry ground lost 35 lbs. more per pole in 8 months than others skidded over ground which was wet and covered with rank vegetation.

It is axiomatic that the rate of evaporation varies with the degree of exposure to atmospheric influences. The form of the pile, its position with regard to prevailing winds, the "lay" of the ground, the presence of underbrush or trees, and the height of the timbers above ground all affect the rate of seasoning just in proportion as they hinder, or promote, free circulation of air and free access of sunshine. Rank vegetation,

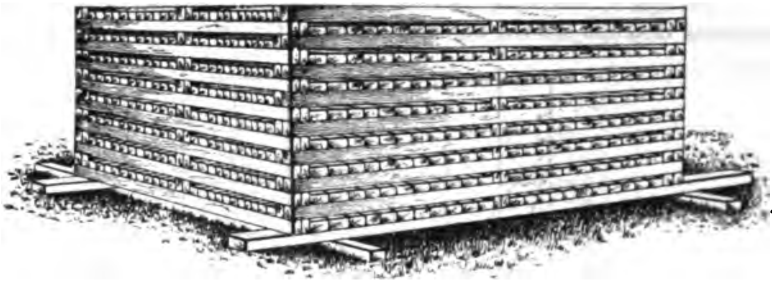


Fig. 50.—Ten-Foot Cross-Arms Piled 28x28; Two Faces of Arms Exposed to Air Circulation.

wet soil, or neighboring bodies of water affect seasoning by increasing the humidity of the atmosphere.

The retardation of seasoning by insufficient exposure requires, of course, carrying a larger stock of timber in the yard, and so involves higher interest and insurance costs. In case of timbers shipped after a given period, slow seasoning requires higher freight costs because of the

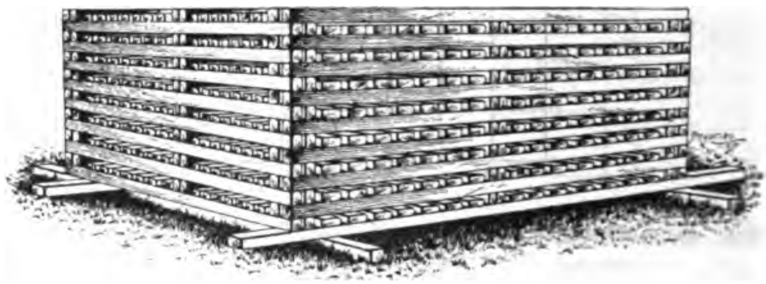


Fig. 51.—Ten-Foot Cross-Arms Piled 20x20; all Faces of Arms Exposed to Air Circulation.

greater weight of water to be transported. Retardation of seasoning also extends the period of danger from insects or fungi which thus have more opportunity to attack the timber before it becomes immune by drying.

SOAKING.

The extreme rapidity with which saturated wood loses moisture when exposed to drying conditions is doubtless responsible for the belief

that the seasoning of timber may be facilitated by soaking it in water. In the tests to determine the effect of this process, timbers which had been soaked for short periods, upon removal from the water, lost the extra moisture so fast that they soon reached practically the same condition as similar timbers not immersed. Whether the soaked timber ultimately reaches a lower moisture content is still open to question. Hemlock ties at Escanaba, Mich., soaked 10 to 20 days, contained slightly more moisture at the end of one year than ties of the same lot which had not been soaked. Loblolly pine cross-arms at Norfolk, Va., soaked 10, 20 and 30 days, contained less moisture after 5 months than the unsoaked arms. The same is true at the end of one year for chestnut poles which had been submerged two weeks. These results are summarized in Table 9:

TABLE 9.—EFFECT OF SOAKING TIMBER ON SUBSEQUENT RATE OF DRYING.

Kind of timber	Days seasoned*	Moisture content	
		Unsoaked	Soaked
		Per cent	Per cent
Hemlock ties	427–439†	48	51
Loblolly pine cross-arms	150	23	18
Chestnut poles	370	40	38

*Includes period of immersion.
†The longer period applies to the soaked ties.

DETERIORATION OF THE WOOD WHILE SEASONING.

Knowledge of the factors which affect the rate of seasoning is important for the prevention of injury to the wood during the drying process. The complaint is not at all uncommon that cross-ties or other timbers of certain species, such as the soft pines, the gums, beech and maple, will decay before they will season. It is believed that this can be prevented usually by piling the timbers so as to dry rapidly. The tree should be barked as soon as felled, and the timbers piled openly. Injury by insects may be prevented in the same manner.*

While quick seasoning prevents injury by decay and insects, it is not always necessary nor desirable. Timber cut and set drying in hot weather checks more seriously than in cold weather, and sometimes becomes "case-hardened" and very resistant to preservative treatment. Timber cut in the late autumn or winter seasons more slowly and evenly; if peeled and properly stacked, or skidded off the ground, it dries enough before warm weather to resist attack by insects or fungi. But whatever the time of cutting, careful attention is needed in piling

*For further information in regard to the prevention of injury to timber product by insects, consult the publications of the Bureau of Entomology, U. S. Department of Agriculture, particularly the following:
Bulletin 58, Part V, "Insect Depredations in North American Forests."
Circular 128, "Insect Injuries to Forest Products."
Circular 156, "Insect Damage to Mine Props and Methods of Preventing Injury."

the timber, either more openly or more closely, according as local climatic and other conditions are found to require.

The belief is prevalent that the difference in the behavior of timber cut at one time of the year from that cut at another is due to inherent differences in the condition of the wood itself. It is frequently stated that wood cut during the winter when the "sap is down" is of better quality or more durable than that cut when the "sap is up." These effects in themselves are doubtless real, but they must be attributed very largely to external conditions rather than to internal conditions of the tree before it is felled. Moreover, contrary to popular belief, a tree contains as much or more sap in winter as in summer. It was shown by early European investigations that the moisture content of trees is relatively high during January and February; during the spring, when transpiration (evaporation) through the buds or young leaves is active, the wood moisture decreases, although the conductive tissues are also more active and the sap flows more freely at this time. Later in the summer the moisture again increases because, perhaps, the mature leaves permit less evaporation; in the autumn months another period of lower moisture content occurs.* The time and extent of these fluctuations vary in different species, and doubtless also with conditions of the weather.

DEGREE OF DRYNESS ATTAINABLE.

The term "air dry" has heretofore been used as a matter of convenience to indicate the lowest moisture condition reached by the various timbers. In most cases, further losses would have occurred if the tests had been continued. In Fig. 52 the weights of lodgepole and longleaf pine, red oak and red gum ties are shown for periods of from 15 to 25 months. In the case of lodgepole pine in Montana seasoned for nearly 2 years, 75 per cent. of the total loss of weight occurred within the first 2 months, and 97 per cent. within 12 months. The curve for longleaf pine in Texas is similar to that for lodgepole; in a test lasting 15 months 91 per cent. of the total loss occurred within 5 months, although the ties were still losing very slightly at the end of the test. The red oak ties were cut in Arkansas and seasoned for 2 years; they dried more slowly than the pine ties, only 75 per cent. of their total loss in weight occurring within the first year. These ties were gaining weight when the last records were taken. This was on account of winter weather, but had the test been continued into the third summer, further decrease in weight doubtless would have occurred. Red gum ties seasoned for two years under conditions similar to the red oak lost within the first year 81 per cent. of the total amount of water evaporated.

Fig. 53, which is plotted from data given by Barlow,† shows that blocks of English oak, 5 in. x 12 in., 8 in. x 16 in., 10 in. x 16 in. in cross-section and 24 to 30 in. long, continued to lose weight for 5½

*From investigations by Hartig in "Die Technichen Eigenschaften des Holzes," by H. Nordlinger, 1860.

†Barlow, Peter—"Essay on Strength and Stress of Timber."

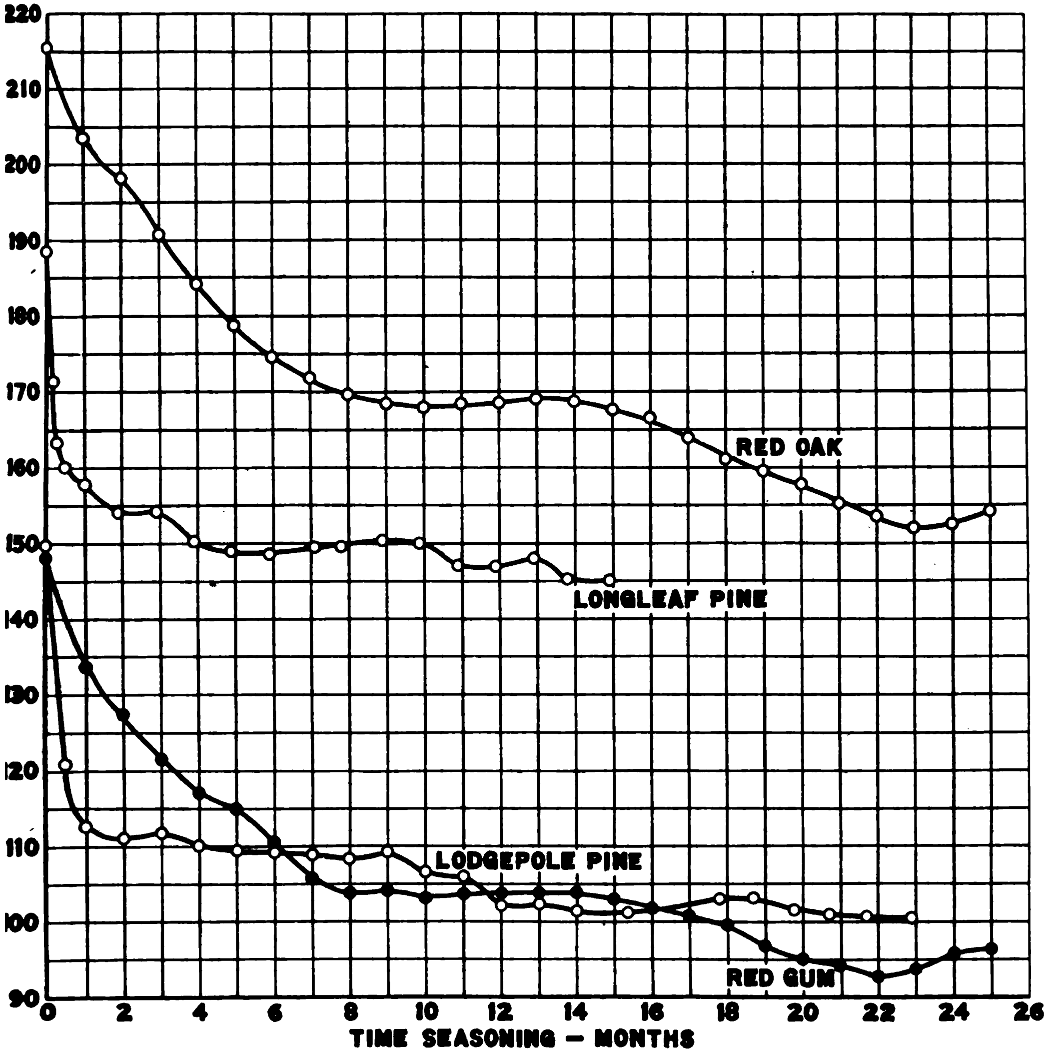


Fig. 52.—Losses in Weight of Ties With Long-Continued Seasoning.

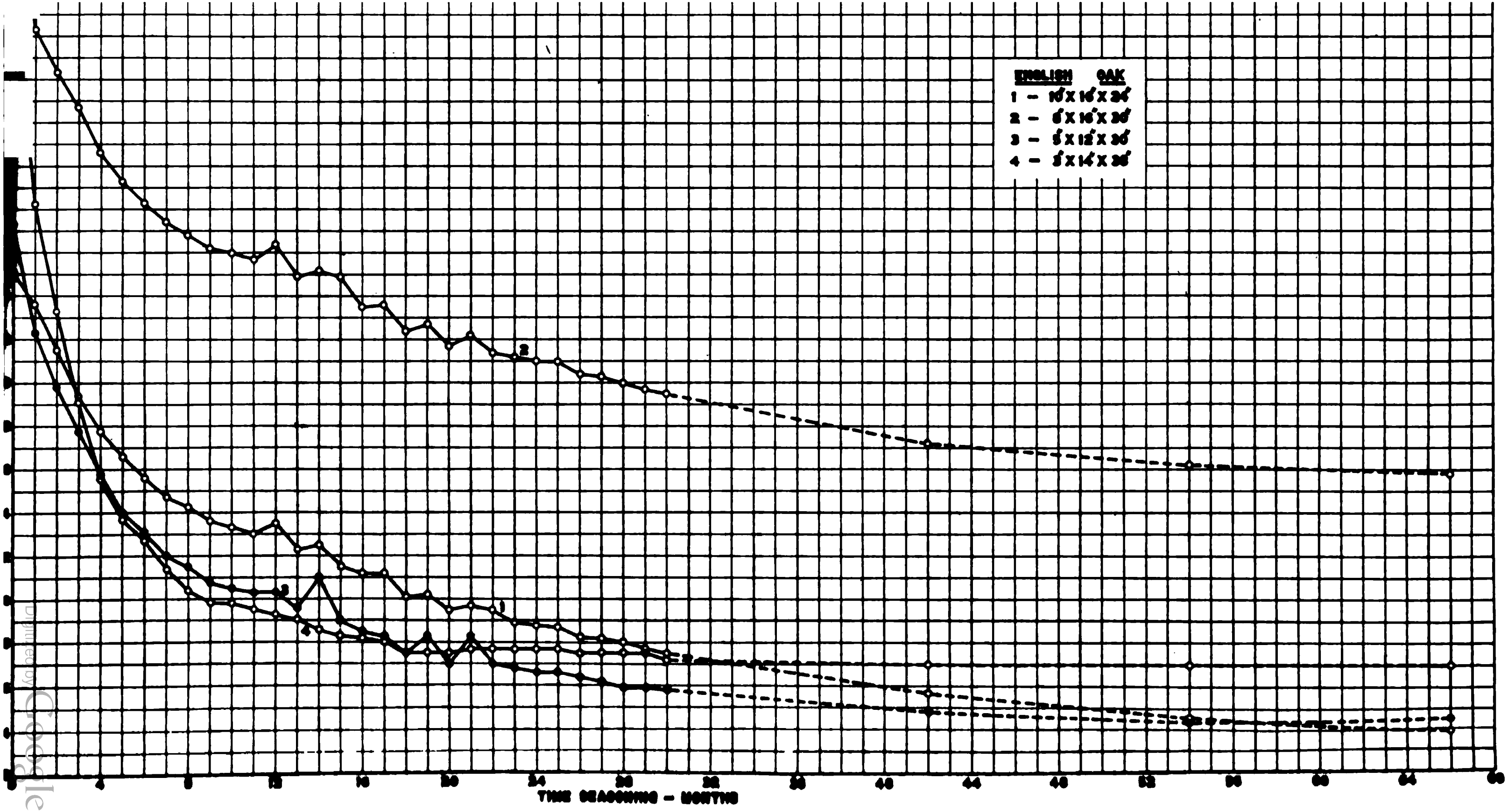


Fig. 53. Loss of Weight of Oak Blocks During Five and One-Half Years' Seasoning

years. One piece, 3 in. x 14 in., was nearly as dry after 2½ years' seasoning as after 5½ years. These blocks were stored in the loft of a blacksmith's shop which was unheated except for the fire of the forge.

The Forest Service records show losses in the weight of Western larch bridge stringers (8 in. x 16 in. in section) throughout a period of 3½ years and of Western hemlock and redwood throughout a period of 3 years (Figs. 44 and 46).

Losses of weight, especially with large timbers, are so gradual after the greater portion of the moisture has been evaporated that it is impossible to fix any particular moisture per cent. to be designated "air dry." The air dry condition depends, of course, on the humidity of the atmosphere; it changes for each climate and season, and varies from day to day.

The moisture contents of small air dry blocks (1½ in. x 1½ in. x 8 in.) of various species of wood determined at New Haven, Conn., are shown in Table 10. These blocks had been seasoned for over a year under cover of a shed and the determinations were made during a period of clear weather.* Under the conditions of this test, the air dry wood contained from 13 to 15 per cent. moisture. In a drier climate the moisture content may go as low as 12 per cent. or lower.

TABLE 10.—MOISTURE CONTENT OF SMALL BLOCKS THOROUGHLY AIR-SEASONED AT NEW HAVEN, CONN.

Species	Moisture content
	Per cent.
Longleaf pine	13.3
Loblolly pine	14.7
Red spruce	15.0
White pine	13.4
Red fir	14.1
White ash	14.4
Hard maple	14.9
Brown ash	14.9
Red gum	14.9
Chestnut	13.8

For most uses structural timber would be considered air dry when it had lost 75 per cent. or more of the total moisture loss possible by air seasoning. As a rule the time required to reach this condition would not be excessive for commercial practice.

It is apparent from the information here presented that, as a rule, timber weighing considerably more than the theoretical air dry wood must be considered "air dry" and used.

SEASONING AFTER TREATMENT.

Fig. 54 shows the gain in weight of lodgepole pine ties during treatment with 3 per cent. (approximately) zinc chloride solution and the

*The specimens were of uniform size and were lying side by side on a rack during the entire time of seasoning. The half-inch discs from which the moisture determinations were made were cut one-half inch from the ends of the blocks on October 14, the weather having been clear for five consecutive days previously. There were two specimens of each species, the figures given being the average of the two.

loss during subsequent seasoning. The ties, which were air seasoned when placed in the cylinder, were subjected to steaming as a part of the treating operation, and gained, on an average, approximately 60 lbs. per tie. When last weighed, a little more than 2 months after they were treated, they were 3 lbs. heavier per tie than before the solution was injected. The same test was applied to ties treated without steam; the result was the same except that the increase in weight was 10 lbs. less per tie. All of this increase was lost by the end of the seasoning

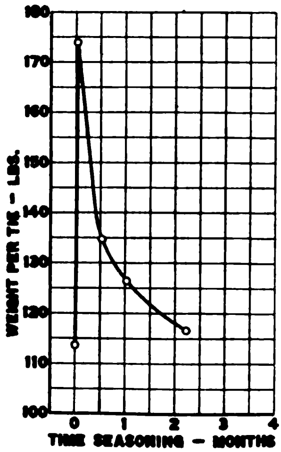


Fig. 54.—Gain in Weight of Lodgepole Pine Ties During Treatment With Zinc Cchloride Solution and Loss During Subsequent Seasoning.

period employed in the first case. The results in both cases are based on two-truck loads of from 28 to 30 ties each.

Red oak ties, treated at the Forest Products Laboratory (Madison, Wis.), lost 61 per cent. of the weight gained during treatment. These ties were treated with approximately 46 lbs. of 3 per cent. zinc chloride solution per tie and were piled about 5 months in the winter and spring (from February to June). Hard maple ties under the same conditions gained 63 lbs. (2.5 per cent. solution) per tie and lost 78 per cent. of this amount. There are, however, no data which afford a comparison between these losses and the losses from green untreated ties under similar conditions.

Under some conditions at least the zinc chloride apparently retards the evaporation of water very appreciably, as shown by the fact that loblolly pine ties treated with a 2.5 per cent. solution and seasoned 8 months at Lafayette, Ind., then weighed 3.1 lbs. more per cu. ft. than before they were treated.*

*Forest Service Circular 39.

SHRINKAGE.

The drying of wood is accompanied by a shrinkage of its volume which begins usually when all water has been evaporated* from the cell cavities, and the cell walls themselves begin to dry out. When this condition is reached, the moisture content is, as a rule, less than 30 per cent.,† but the moisture content in a large stick is not evenly distributed and the outer portions dry first, so some shrinkage occurs almost as soon as seasoning begins. This is seen in Fig. 55, which shows the per cent. of green area in cross-section of Douglas fir, Western hemlock and Western larch beams as compared with loss of moisture. It will be noted that the reduction of proportional green area becomes more pronounced as the beams approach an air dry condition.

Table 11 shows the linear shrinkage in the radial and tangential directions for small blocks of a number of species; the shrinkage from the green to the air dry, or approximately air dry condition, and from the green to the oven dry state is shown separately. In all cases the greater part of the shrinkage occurred after the blocks were placed in the oven. These points are significant since they show that partial air seasoning has very little effect in preventing the subsequent shrinkage of timbers, and that complete air seasoning is not sufficient if the wood is later to be subjected to further drying, as by use in artificially heated structures.

Shrinkage tangentially is nearly twice as great as radially. Longitudinal shrinkage is so small that it may be disregarded. The shrinkage in circumference of air-seasoned poles was extremely small, being less than 1 per cent.; this was due largely to the fact that the poles were not sufficiently dry when the tests ended to cause much shrinkage, and it was due also, perhaps, partly to the checking which occurred.

TABLE 11.—RADIAL AND TANGENTIAL SHRINKAGE OF VARIOUS SPECIES*

Species	No. of tests	Size of specimen	Average moisture content		Average Shrinkage			
					Green to air-dry		Green to oven dry	
			Green	Air dry	Radial	Tangential	Radial	Tangential
		Inches	Percent.	Per cent.	Percent.	Per cent.	Percent.	Per cent.
Western yellow pine	10	3x3x12	61.3	14.5	1.6	2.0	4.0	5.0
Lodgepole pine.....	19	3x3x10	39.9	17.0	1.7	2.7	4.7	6.7
Englemann spruce	20	3x3x10	87.1	19.2	.6	2.0	3.7	6.7
Englemann spruce	16	3x3x12	35.9	20.5	.3	1.0	3.3	6.6
Alpine fir..........	8	3x3x12	84.0	22.8	.3	1.3	3.0	6.0
Red fir............	6	3x3x12	26.9	14.9	.6	1.6	3 3	4.7
White fir..........	13	3x3x12	49.0	16.7	.3	2.0	3.3	5.6
Douglas fir.........	30	3x3x12	32.6	15.3	2.3	3.0	5.0	7.6

*Tests made by the Forest Service at the Seattle, Washington, Laboratory.

*Eucalyptus, which begins to shrink at once with any loss of moisture from the green wood, seems to be an exception to this rule.
†Forest Service Bulletin 70 and Circular 108.

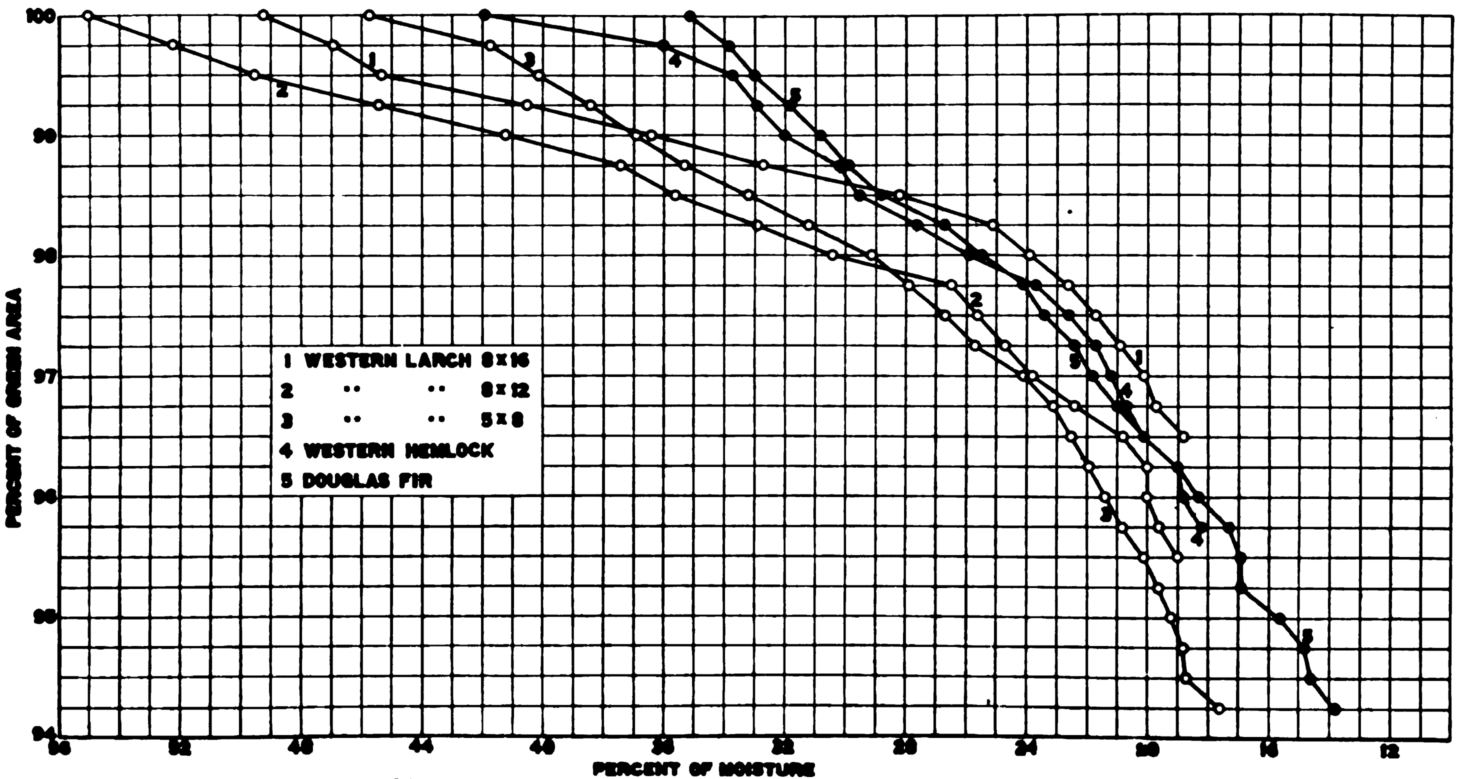


Fig 55.—Relation of Cross-Sectional Area to Moisture Content.

SPECIFIC GRAVITY AND WEIGHT OF WOOD.

Table 12 gives the specific gravities and oven dry weights per cubic foot for a number of species of wood. These calculations are based on the green volume; in other words, the weight given is the oven dry weight of what was, when green, 1 cu. ft. of wood. Because of the shrinkage that occurs, a cubic foot of dry wood contains a greater mass, or weight, of wood substance than a cubic foot of green wood; hence the actual weight per unit volume of dry wood is from 10 to 20 per cent. higher than that of green wood. However, the values given are more nearly correct for calculating the weight of seasoned and partially seasoned wood than if based on oven dry volume, since the greater part of the total shrinkage occurs after the air dry stage has been passed.

In applying these values, the weight of the water in the wood must, of course, be added. As explained previously, in wood completely air dried the water weighs from 12 to 15 per cent. of the oven dry weight, and it weighs more than this in wood which in commercial practice is usually considered air dry. In green wood the amount of water varies within very wide limits,* depending upon species, age of the tree, conditions of growth, and other factors.

*In the case of white fir (Abies concolor) the water in the green wood may amount to from 100 to nearly 200 per cent. of its dry weight, while in the heartwood of a freshly cut tree of longleaf pine the water may not amount to more than 35 per cent. of the dry weight of the wood.

TABLE 12.—SPECIFIC GRAVITY AND WEIGHT PER CUBIC FOOT OF VARIOUS SPECIES

Common Name	Botanical Name	Locality	No. of trees	Average dry weight per cu. ft.	Dry Specific Gravity*		
					Average	Range in corresponding bolts from different trees	Range in bolts from same tree
CONIFERS:				Pounds			
Arborvitae	Thuja occidentalis	Shawano Co., Wis.	5	18.25	.293	.273–.317	.248–.320
Cedar, Incense	Libocedrus decurrens	Weed, Cal.	9	22.60	.363	....	....
Cypress, Bald	Taxodium distichum	St. John The Baptist Parish, La.	4	28.15	.452	.410–.510	.404–.422
Fir, Balsam	Abies balsamea	Coos Co., N. H.	1	20.42	.328	....	....
Fir, White	Abies concolor	Madera Co., Cal.	5	21.80	.350	.333–.368	.313–.351
Fir, Alpine	Abies lasiocarpa	Grand Co., Colo.	5	19.06	.306	.282–.323	.296–.315
Fir, Douglas	Pseudotsuga taxifolia	Johnson Co., Wyo.	5	26.03	.418	.388–.452	.423–.461
Hemlock	Tsuga canadensis	Marathon Co., Wis.	5	21.18	.340	.300–.365	.308–.365
Pine, Lodgepole	Pinus contorta	Grand Co., Colo.	5	23.05	.370	.352–.404	.353–.376
Pine, Lodgepole	Pinus contorta	Johnson Co., Wyo.	5	23.10	.371	.355–.389	....
Pine, Longleaf	Pinus palustris	Tangipahoa Parish, La.	5	32.90	.528	.473–.563	.373–.528
Pine, Red	Pinus resinosa	Shawano Co., Wis.	5	27.40	.440	.412–.492	.327–.459
Pine, Shortleaf	Pinus echinata	Malvern, Ark.	70	29.71	.477	....	....
Pine, Sugar	Pinus lambertiana	Madera Co., Cal.	5	22.42	.360	.343–.385	.331–.363
Pine, Western Yellow	Pinus ponderosa	Coconino Co., Ariz.	5	21.99	.353	.322–.406	....
Pine, Western Yellow	Pinus ponderosa	Madera Co., Col.	5	23.49	.377	.339–.403	.329–.419
Pine, White	Pinus strobus	Shawano Co., Wis.	5	22.60	.363	.344–.389	.320–.385
Redwood	Sequoia sempervirens	Humboldt Co., Cal.	....	20.80	.334	....	....
Redwood	Sequoia sempervirens	Medocino Co., Cal.	....	22.80	.366	....	....
Spruce, Engelmann	Picea engelmanni	Grand Co., Colo.	5	....	....	....	....
Spruce, Red	Picea rubens	Coos Co., N. H.	4	24.67	96	....	....
Spruce, White	Picea canadensis	Coos Co., N. H.	2	19.80	.318	....	....
Tamarack	Larix laricina	Marathon and Shawano Cos., Wis.	5	30.59	.491	.463–.516	....
HARDWOODS:							
Ash, Black	Fraxinus nigra	Marathon Co., Wis.	....	29.03	.466	....	....
Ash, White	Fraxinus americana	Stone Co., Ark.	5	34.27	.550	.498–.606	....
Ash, White	Fraxinus americana	Richland Parish, La.	5	32.15	.516	.504–.531	.418–.517
Basswood	Tilia americana	Marathon Co., Wis.	3	19.62	.315	.279–.369	.261–.302
Beech	Fagus atropunicea	Hendricks and Morgan Cos., Ind.	5	34.64	.556	.517–.579	.564–.600
Birch, Yellow	Betula lutea	Marathon Co., Wis.	5	33.95	.545	.519–.573	.524–.535
Elm, Rock	Ulmus pubescens	Marathon Co., Wis.	....	36.00	.578	....	....
Elm, Slippery	Ulmus pubescens	Hendricks Co., Ind.	1	33.70	.541	....	....
Elm, White	Ulmus americana	Hendricks Co., Ind.	1	38.00	.610	....	....
Gum, Red	Liquidambar styraciflua	New Madrid Co., Mo.	20	27.03	.434	....	....
Hackberry	Celtis occidentalis	Hendricks Co., Ind.	1	31.40	.504	....	....

*Based on green volume.

TABLE 12—Continued

Common Name	Botanical Name	Locality	No. of trees	Average dry weight per cu. ft.	Dry Specific Gravity* Average	Range in corresponding bolts from different trees	Range in bolts from same tree
HARDWOODS				Pounds			
Hickory, Big Shell Bark	Hicoria laciniosa	Sardis, Miss	10	37.45	.601	.508-.642	
Hickory, Big Shell Bark	Hicoria laciniosa	Napoleon, Ohio	9	41.50	.666	.635-.696	
Hickory, Butternut	Hicoria minima	Napoleon, Ohio	11	38.89	.624	.594-.659	
Hickory, Mockernut	Hicoria alba	Sardis, Miss	8	37.75	.606	.585-.642	
Hickory, Mockernut	Hicoria alba	Chester Co., Pa	11	41.25	.662	.603-.719	
Hickory, Mockernut	Hicoria alba	Webster Co., W. Va	1	41.50	.666		.666
Hickory, Nutmeg	Hicoria myristicaeformis	Sardis, Miss	5	34.77	.558	.498-.588	
Hickory, Pignut	Hicoria glabra	Sardis, Miss	4	39.07	.627	.599-.649	
Hickory, Pignut	Hicoria glabra	Napoleon, Ohio	10	41.57	.667	.620-.704	
Hickory, Pignut	Hicoria glabra	Chester Co., Pa	27	41.57	.667	.604-.714	
Hickory, Pignut	Hicoria glabra	Webster Co., W. Va	19	42.19	.677	.602-.732	
Hickory, Shagbark	Hicoria ovata	Sardis, Miss	4	37.89	.608	.599-.625	
Hickory, Shagbark	Hicoria ovata	Napoleon, Ohio	9	40.25	.646	.593-.701	
Hickory, Shagbark	Hicoria ovata	Chester Co., Pa	1	38.44	.617		.617
Hickory, Shagbark	Hicoria ovata	Webster Co., W. Va	10	40.70	.653	.604-.689	
Hickory, Water	Hicoria aquatica	Sardis, Miss	2	39.25	.630	.585-.675	
Locust, Honey	Gleditsia triacanthos	Hendricks Co., Ind	1	43.30	.695		.695
Maple, Red	Acer rubrum	Marathon Co., Wis		31.90	.512		
Maple, Sugar	Acer saccharum	Hendricks and Morgan Cos., Ind	5	34.02	.546	.520-.561	.541-.564
Maple, Sugar	Acer, saccharum	Marathon Co., Wis		35.95	.577		
Oak, Post	Quercus minor	Stone Co., Ark	5	36.76	.590	.529-.620	
Oak, Red	Quercus rubra	Stone Co., Ark	5	35.45	.569	.538-.635	
Oak, Red	Quercus rubra	Hendricks and Morgan Cos., Ind	6	35.40	.568	.479-.614	
Oak, Red	Quercus rubra	Richland Parish, La	5	35.20	.565	.531-.581	.520-.550
Oak, Swamp White	Quercus platanoides	Hendricks Co., Ind	1	39.70	.637		
Oak, Tanbark	Quercus densiflora	Willits, Cal		36.45	.585		
Oak, White	Quercus alba	Stone Co., Ark	5	37.00	.594	.555-.651	
Oak, White	Quercus Alba	Hendricks, Marion and Morgan Cos., Ind	5	37.58	.603	.575-.638	.593-.637
Oak, White	Quercus alba	Richland Parish, La	5	37.39	.600	.560-.646	
Oak, Yellow	Quercus velutina	Stone Co., Ark	5	35.70	.573	.534-.608	
Oak, Yellow	Quercus velutina	Marathon Co., Wis		34.26	.550		
Osage Orange	Toxylon pomiferum	Morgan Co., Ind	1	47.40	.761		
Sycamore	Platanus occidentalis	Hendricks Co., Ind	5	28.29	.454	.434-.467	.444-.477
Tupelo	Nyssa aquatica	St. John the Baptist Parish, La	1	29.60	.475		

*Based on green volume.

APPENDIX.

The following publications of the Forest Service have been consulted in the preparation of this Bulletin.*

Bulletin 10, "Timber," by Filibert Roth.
Bulletin 41, "Seasoning of Timber," by Hermann von Schrenk.
Bulletin 84, "Preservative Treatment of Poles," by W. H. Kempfer.
Bulletin 88, "Properties and Uses of Douglas Fir," by McGarvey Cline.
Bulletin 108, "Tests of Structural Timbers," by McGarvey Cline and A. L. Heim.
Bulletin 115, "Structural Properties of Western Hemlock," by O. P. M. Goss.
Bulletin 118, "Prolonging the Life of Cross-ties," by Howard F. Weiss.
Bulletin 122, "Structural Properties of Western Larch," by O. P. M. Goss.
Bulletin 126, "Experiments in the Preservative Treatment of Red Oak and Hard Maple Railway Ties," by Francis M. Bond.
Circular 39, "Experiments on the Strength of Treated Timber," by W. Kendrick Hatt.
Circular 103, "Seasoning of Telephone Poles," by Henry Grinnell.
Circular 132, "The Seasoning and Preservative Treatment of Hemlock and Tamarack Cross-ties," by W. F. Sherfesee.
Circular 136, "The Seasoning and Preservative Treatment of Arborvitæ Poles," by C. Stowell Smith.
Circular 146, "Experiments with Railway Cross-ties," by H. B. Eastman.
Circular 147, "Progress in Chestnut Pole Preservation," by Howard F. Weiss.
Circular 151, "The Preservative Treatment of Loblolly Pine Cross-arms," by W. F. Sherfesee.
Circular 193, "Mechanical Properties of Redwood," by A. L. Heim.
Circular 213, "Mechanical Properties of Woods Grown in the United States."

*Much information was also obtained from unpublished manuscripts and data sheets in the files of the Forest Service.

PLATE I.

Plate I. Fig. 1.—7x2 Form.
TIES PILED FOR RAPID SEASONING.

PLATE I

Fig. 2.—8x1 Form.
TIES PILED FOR RAPID SEASONING.

PLATE II.

Plate II. Fig. 1.—Unpeeled Ties in Solid Piles.
(In a warm, moist climate timbers piled in this manner are liable to insect attack and decay before they become seasoned.)

PLATE II.

Fig. 2.—Unpeeled Mine Props Closely Ranked and in Contact With Ground.

(In a warm, moist climate timbers piled in this manner are liable to insect attack and decay before they become seasoned.)

PLATE III.

Plate III. Fig. 1.—Wrong Method of Piling Poles for Seasoning.

PLATE III.

Fig. 2.—Right Method of Piling Poles for Seasoning.

PLATE IV.

Plate IV. Fig. 1.—Bridge Stringers Piled So As to Permit Air Circulation and Hasten Drying.

PLATE IV.

Fig. 2.—A Good Way of Piling Fence Posts.

ROLLING LOADS ON BRIDGES.

By J. E. Greiner, Consulting Engineer.

INTRODUCTION.

Coincident with the introduction of a particularly heavy type of locomotive is always the question as to whether bridges are being constructed of sufficient strength to safely carry this heavy engine and its possible future development.

This same question has been cropping out time and time again during the past thirty years or more, and the answer has heretofore frequently been evidenced by the construction of somewhat stronger bridges, but in many cases to an extent merely sufficient to anticipate the increasing weight of rolling stock for a very brief period.

During each successive revision of the specifications it was believed that the practical limits of locomotive weights and car capacities had been fully anticipated, but the fallacy of this belief has been demonstrated so frequently that now few engineers feel inclined to assert, with any degree of confidence, at what point or at what time this development will have reached its limit. It is apparent that we have not yet passed the period of expansion and development, and the question as to whether the structures now being built are of sufficient strength depends entirely upon future development in the type and weight of the rolling stock and the accuracy with which the designer has anticipated this development.

This discussion has a direct bearing on this question and is the result of an investigation made recently with a view of ascertaining the heaviest engines in operation, the requirements of bridge specifications and the anticipated development as indicated by the capacity of modern bridges. It is, therefore, hoped that the presentation of this matter at the present time will be of some practical use to those interested.

HEAVIEST LOCOMOTIVES.

Since 1835, about the time the first bridge was built for carrying trains, locomotives have developed from the miniature 4-wheel grasshopper weighing less than 22,000 lbs. to the enormous 24-wheel articulated type weighing 616,000 lbs.

About 20 years ago the heaviest engine in service on the Baltimore & Ohio was a Consolidation weighing about 134,000 lbs.; at the present time this road has articulated engines weighing 463,000 lbs. Similar increases have taken place quite generally on other roads until the heaviest engines of each type have now reached the weights given in Table 1.

This table also gives the weight and wheel base of double-header engines with their tenders for all types excepting the articulated, where a single engine with tender is used in comparison. Attention is called to the fact that the wheel bases of all double-header engines, excepting the electric types, are considerably larger than Cooper's E series generally used for bridge designs. The articulated types, being single, have shorter wheel bases than the double-headers of other types.

The weight per foot given in the last column of this table is the total weight of engines and tenders divided by the total wheel base, double-headers for all except the articulated types. This weight per foot does not signify anything in regard to the relative effects, on bridges, of the different types of engines, and, therefore, cannot be used in comparing these effects. It is given here merely for the purpose of illustrating this fact, which will be apparent upon comparing these weights with the relative stress effects given in Table 3.

The heaviest locomotives in actual service on thirty-six American railways are given in Table 2, which table also indicates contemplated increases.

The increases from the 22,000-lb. grasshopper used on the Baltimore & Ohio in 1835 to the articulated type weighing 463,000 lbs. has been rapid and remarkable and is illustrated by the following data, which shows the heaviest engines in actual service on the Baltimore & Ohio Railroad from 1835 to date:

DATA SHOWING ENGINE DEVELOPMENT ON BALTIMORE AND OHIO RAILROAD.

Type.	Date.	Weight.
Grasshopper	1835	22,000 lbs.
Winans' Camel, 8-wheel	1851	74,600 "
Perkins' 10-wheel	1863	90,800 "
Consolidation	1873	105,200 "
Consolidation	1881	108,600 "
Mogul	1886	113,200 "
Consolidation	1887	115,600 "
Consolidation	1888	125,000 "
Baldwin, 10-wheel	1890	133,000 "
Consolidation	1892	134,200 "
Consolidation	1894	160,800 "
Electric Motor	1895	190,000 "
Consolidation	1905	208,500 "
Pacific	1906	229,500 "
Articulated	1911	463,000 "

The above shows an increase from 133,000 lbs. in 1890 to 463,000 lbs. in 1911, which is about 248 per cent. in the past 21 years. There are much heavier engines in use on other roads.

The maximum axle load in 1835 was 5,500 lbs., while at present it has gone beyond 65,000 lbs., with limit not yet reached.

TABLE 1—HEAVIEST LOCOMOTIVES OF EACH TYPE.

Type.	Engine Alone.		*Double-Header.		
	Weight, Lbs.	Wheel Base, Ft.	Weight, Lbs.	Wheel Base, Ft.	Weight, Per Ft.
Atlantic	214,800	30.79	728,400	127.76	5,700
Prairie	244,700	34.25	807,500	132.92	6,070
Consolidation	260,100	26.50	860,400	131.81	6,520
12 Wheel	262,000	27.08	817,400	130.15	6,280
Decapod	267,000	29.83	802,000	127.00	6,320
Pacific	270,000	35.20	865,400	142.48	6,070
Mikado	305,000	35.00	960,000	150.00	6,400
12 Wheel Articulated	334,500	30.66	473,800	64.56	7,340
10 Coupled	361,000	43.50	1,074,000	161.00	6,670
20 Wheel Articulated	478,000	59.80	703,600	99.70	7,060
16 Wheel Articulated	493,000	40.17	588,000	82.58	7,130
24 Wheel Articulated	616,000	65.92	841,600	105.82	7,950
12 Wheel Electric	300,400	38.50	600,800	86.50	6,950
16 Wheel Electric	320,000	44.22	640,000	102.84	6,220
†Cooper's E-50	225,000	23.00	710,000	104.00	6,830
†Cooper's E-60	270,000	23.00	852,000	104.00	8,190

*Weight and wheel base for articulated engines are given for one engine and tender.

†Cooper's E-50 and E-60 typical consolidation engines are given for comparison.

TABLE 2—HEAVIEST LOCOMOTIVES IN ACTUAL SERVICE ON 36 AMERICAN RAILWAYS.

	Locomotives in Service.		Under Consideration.	
Railway.	Type.	Weight Lbs.	Type.	Weight. Lbs.
N. Y., N. H. & H.	Pacific	229,500	Pacific	235,000
B. & M.	Pacific	equal to E-48	....	....
N. Y. C. Lines	Pacific	266,100	....	....
Erie	Consolidation	260,100	Mikado	305,000
P. R. R.	Pacific	269,800	....	....
L. V.	Pacific	241,400	....	....
P. & R.	Consolidation	222,000	....	....
B. & O.	Mallet	463,000	....	....
N. & W.	Mallet	400,000	....	....
C. & O.	Mallet	392,000	Mallet	400,000
Virginian	Mallet	455,000	....	....
S. A. L.	Consolidation	212,000	....	....
Southern	Mallet	366,000	....	....
A. C. L.	Consolidation	171,000	....	....
L. & N.	Consolidation	224,000	....	....
Wabash	Consolidation	223,800	....	....
B. & L. E.	Consolidation	254,000	....	....
I. C.	Consolidation	223,000	Mikado	280,000
Pere Marquette	Consolidation	217,000	....	....
M., St. Paul & S. S. M.	Pacific	253,800	....	....
C. & A.	Mallet	323,400	....	....
C. & N. W.	Pacific	238,000	....	....
Great Northern	Consolidation	216,600	....	....
C., M. & St. P.	Mikado	260,500	....	....
C., B. & Q.	Mallet	354,500	Mallet	463,000
A., T. & S. F.	Double Santa Fe	616,000	....	....
C., R. I. & P.	Consolidation	238,900	....	....
N. P.	Mallet	435,200	....	....
M. P.	Pacific	251,000	Mallet	?
S. P.	Mallet	437,000	....	....
St. L. & S. F.	Mallet	416,000	....	....
M., K. & T.	Pacific	228,000	....	....
Grand Trunk	Consolidation	211,200	Mikado	275,000 abt.
Canadian Pacific	Mallet	261,900	....	....
C. N.	Consolidation	181,400	Consol	?
N. Rys. of M.	Mallet	338,000	....	....

BRIDGE SPECIFICATION REQUIREMENTS.

The specification loading for bridge design as now in use by the various railroads is given in Table 3, which table also gives the impact allowances and permissible unit-stresses. The simplest manner of comparing these various specified loadings, including their different impacts and unit-stresses, is by reducing them to an equivalent loading on the basis of the American Railway Engineering Association Specifications. These specifications provide for a consolidation type of engine known as Cooper's E-40, E-50, E-60 series, depending upon whether the weight on each driving axle is forty, fifty or sixty thousand pounds. The equivalent loading given in the sixth column of Table 3, therefore, means that the specified loading, impacts and unit-stresses, as adopted by the various railways, are practically equivalent in their effects on bridges to the Cooper's E series loading noted, when used in connection with the American Railway Engineering Association Specifications.

This table also shows changes under consideration by a number of railways. It will be observed by reference to the table, column 6, that eleven roads are building bridges for a strength practically equal to E-60 bridges, four for E-57, seven for E-55, one for E-53, eleven for E-50, four for loads under E-50 and one for loads over E-60. Of those roads which are now designing bridges for E-50 or under, two propose to change to E-60 and three to loading in excess of E-50 in the near future.

It may be reasonably assumed that the specifications in force, or the proposed changes, represent the views of the engineering department of the various railways relative to the sufficiency of the present requirements for meeting future conditions, and on this assumption

One road considers E-65 insufficient,
Thirteen roads consider E-60 sufficient,
Fifteen roads consider E-55 sufficient,
Ten roads consider E-50 sufficient.

In order to determine the relative effects, on bridges, of the various heaviest types of engines in service and the usual specification E-50 and E-60 class, the maximum shearing and bending stresses produced by each type were calculated for spans ranging from 10 ft. to 100 ft., all locomotives, excepting the articulated types, being considered as running double-headers drawing a train of 5,000 lbs. per foot of track. On the assumption that the maximum stress produced by E-50 class is represented by unity, the proportional maximum stress produced by the various locomotives on bridges under 100 ft. is given in Table 4.

It is fortunate for our bridges that the stresses produced by the heaviest engines are not in direct proportion to the weight as compared with E-50 type. For instance, the 24-wheel articulated engine weighs 174 per cent. more than E-50, but produces increased stresses varying from 15 per cent. to 33 per cent. The 16-wheel articulated type weighs 119 per cent. more, but produces increased stresses varying from 26 per cent

TABLE 8—BRIDGE SPECIFICATION LOADING.

Railway.	Engine. Type.	Engine. Weight, 1,000 Lbs.	Impact.	Tensile Unit.	Equiv. Loading.	Proposed Changes.
P. R. R. West	excess	60.0	....	$7,000\left(1+\frac{M}{M}\right)$	E-65	10 per cent
N. Y., N. H. & H.	E-60	270.0	A. R. E. A.	16,000	E-60	....
A. C. L.	"	270.0	"	16,000	"	....
B. & L. E.	"	270.0	"	16,000	"	....
Pere Marquette	"	270.0	"	16,000	"	....
C., C. & O.	"	270.0	"	16,000	"	....
G. N.	"	270.0	"	16,000	"	....
C. & O.	Artic.	468.0	"	16,000	"	....
C., B. & Q.	Consol.	252.0	Special	$10,000\left(1+\frac{D}{D+L}\right)$	"	....
A., T. & S. F.	"	291.0	....	Special	"	....
W. Md. Ry.	Artic.	488.0	Special	16,000	"	....
P. & R.	E-55	247.5	A. R. E. A.	15,000	"	....
S. P.	Consol.	240.0	....	Special	E-57	....
N. & W.	Special	275.0	Special	15,000	"	....
Virginian	E-60	270.0	A. R. E. A.	17,000	"	....
C., M. & St. P.	E-55	247.5	....	Special	"	....
Southern	E-55	247.5	A. R. E. A.	16,000	E-55	....
I. C.	"	247.5	"	16,000	"	....
C. & N. W.	"	247.5	"	16,000	"	....
C., R. I. & P.	"	247.5	"	16,000	"	....
St. L. & S. F.	"	247.5	"	16,000	"	....
Nat. Rys. of M.	E-60	270.0	....	Special	"	....
C. & A.	E-50	225.0	....	Special	"	....
N. Y. C. Lines	E-60	270.0	A. R. E. A.	18,000	E-53	....
B. & M.	E-50	225.0	A. R. E. A.	16,000	E-50	....
Erie	"	225.0	"	16,000	"	E-60
Wabash	"	225.0	"	16,000	"	....
M. P.	"	225.0	"	16,000	"	E-55
M., K. & T.	"	225.0	"	16,000	"	....
Grand Trunk	"	225.0	"	16,000	"	....
Can. Pac.	"	225.0	"	16,000	"	....
B. & O.	"	225.0	"	16,000	"	....
M., St. P. & S. S. M.	E-55	247.5	....	Special	"	....
L. & N.	Consol.	232.0	A. R. E. A.	17,000	"	E-53
N. P.	"	233.0	....	Special	"	....
L. V.	E-50	225.0	....	Special	E-47	E-60
S. A. L.	"	225.0	A. R. E. A.	17,000	"	....
C. N.	Consol.	211.5	Special	16,000	"	....
P. R. R. East	Pacific	292.0	Special	16,000	E-45	Mallet

to 34 per cent. The 20-wheel articulated type weighs 112 per cent. more, while the stresses are increased only from 1 per cent. to 14 per cent. The 10-coupled engine weighs 60 per cent. more, while the stresses are increased from 0.0 per cent. to 26 per cent. Other engines which weigh considerably more than the E-50 produce stresses ranging from 83 per cent. to 116 per cent. of those caused by the E-50, and the excess stresses are mostly in very short spans.

The above refers to spans under 100 ft. For greater lengths the stresses will in many cases be less, and in no case will they be in excess of those mentioned above.

TABLE 4—RELATIVE STRESSES PRODUCED BY HEAVIEST LOCOMOTIVES—SPANS 10 FT. TO 100 FT.

Class.	Actual Weight.	Proportional Weight.	Proportional Stress.	
			From	To
E-50	225,000	1.00	1.00	1.00
Atlantic	214,800	0.96	0.83	1.15
Prairie	244,700	1.09	0.88	1.03
Consolidation	260,100	1.16	0.99	1.14
12 Wheel	262,000	1.17	1.00	1.14
Decapod	267,000	1.19	0.96	1.07
Pacific	270,000	1.20	0.93	1.08
Mikado	305,000	1.36	1.02	1.16
12 Wheel Articulated	334,500	1.49	0.98	1.15
10 Coupled	361,000	1.60	1.00	1.26
20 Wheel Articulated	478,000	2.12	1.01	1.14
16 Wheel Articulated	493,000	2.19	1.26	1.34
24 Wheel Articulated	616,000	2.74	1.16	1.33
12 Wheel Electric Motor	300,400	1.33	0.83	0.98
16 Wheel Electric Motor	320,000	1.42	0.84	0.98

CAPACITY OF BRIDGES.

All bridgemen know that properly designed bridges, as well as steel hopper cars, may be loaded considerably beyond their nominal capacity, and that they will carry a definite amount of overload regularly and continuously without requiring any closer attention than usually bestowed under ordinary good maintenance conditions. This capacity for overload provides to a large extent for future increases and developments.

We know from numerous tests and long experience that bridges properly designed and constructed of proper material and with members proportioned in accordance with specifications equally as good as the standard adopted by the American Railway Engineering Association, so long as maintained in good condition, will safely withstand an overload of 50 per cent. without any traffic or speed restrictions; that such a bridge may be subjected to an occasional overload considerably in excess of 50 per cent., and this without speed restrictions; and if the speed is regulated, the bridge will stand an occasional overload of 100 per cent.

This statement is consistent with the writer's personal experience with the maintenance of structures in the past 25 years, and is somewhat more conservative than has been the successful practice of a num-

ber of railway engineers. Therefore, it should be clearly understood by the operating officials of railways that a bridge of the nominal E-50 capacity, that is, one designed for Cooper's E-50 loading in accordance with the American Railway Engineering Association's Standard Specifications, will not reach its full regular traffic capacity until the different classes of engines now in service shall have about the weights given in Table 5, and an E-60 bridge not until these engines have increased to the extent shown in Table 6.

An examination of these tables will show that the regular service capacity of an E-50 or an E-60 bridge will take care of engines having an increased weight over those now in service to the following extent:

Types.	E-50.	E-60.
16 and 24-Wheel Articulated......	12 per cent.	34 per cent.
10-Coupled	19 per cent.	43 per cent.
Mikado, 12 and 20-Wheel Articulated, Atlantic, Consolidation, 12-Wheel Type................	30 per cent.	56 per cent.
Pacific and Decapod...............	39 per cent.	67 per cent.
Prairie	46 per cent.	75 per cent.
Electric	53 to 61 per cent.	84 to 94 per cent.

The capacity of these classes of bridges when subjected to occasional loads or to regular loads operated under restricted speed will be considerably in excess of that indicated above. For example, an E-50 bridge with an overload of 75 per cent. which, when the bridge is in good condition and up to the American Railway Engineering Association Standard in design, is perfectly safe for occasional loads or regular loads under restricted speed, will carry engines weighing in excess of the engines now in use to about the extent indicated below:

16 and 24-Wheel Articulated Engines..................	30 per cent.
10-Coupled	39 per cent.
Mikado, 12 and 20-Wheel Articulated, Atlantic, Consolidation and 12-Wheel Type Engines.............	52 per cent.
Pacific and Decapod..................................	62 per cent.
Prairie	70 per cent.
Electric	79 to 88 per cent.

It will be seen from the above that loads which strain an E-60 bridge to its *regular service capacity* can be operated *occasionally* over an E-50 bridge, and *even regularly when speed is restricted.*

HAVE PRESENT BRIDGES SUFFICIENT STRENGTH?

In view of past experience, it is perhaps reasonable to assume that some of the heavy types indicated in Table 5 as developing the full regular service capacity of an E-50 bridge may probably be operated regularly over heavy grade divisions, but experience with the present heaviest loco-

motives does not indicate that still heavier types will ever be proper and economical on low-grade divisions. But suppose they should be operated regularly on all divisions, whether high or low grade, then an E-50 American Railway Engineering Association Specification bridge will have ample capacity to take care of them.

TABLE 5—FULL REGULAR SERVICE TRAFFIC CAPACITY FOR E-50 BRIDGES BASED ON AN OVERLOAD OF 50 PER CENT.

Locomotives.	Weight.	Wheel Base.	Average Axle Load.	Percentage of Increase.†
Cooper's E-75	337,500	23.00	75,000	50.0
*Atlantic	280,000	30.79	82,400	31.0
Prairie	356,300	34.25	82,600	46.0
Consolidation	342,800	26.50	75,600	32.0
12-Wheel	344,800	27.08	73,000	32.0
Decapod	374,300	29.83	66,400	40.0
Pacific	375,000	35.20	81,700	39.0
Mikado	394,200	35.00	77,900	29.0
12-Wheel Articulated	436,200	30.66	72,600	30.0
10-Coupled	429,800	43.50	71,700	19.0
20-Wheel Articulated	629,000	59.80	70,800	32.0
16-Wheel Articulated	552,000	40.17	62,800	12.0
24-Wheel Articulated	695,000	65.92	62,000	13.0
12-Wheel Electric	460,000	38.50	78,800	52.0
16-Wheel Electric	516,000	44.22	64,500	61.0

*The Atlantic type applies to spans under 15 ft.; for greater spans the weight of this class of engine would run over 60 per cent. in excess of the heaviest type now in service.

†Percentages of increase in column 5 represent the approximate increase in weight of locomotives and driving loads in excess of the maximum weights now in actual use.

TABLE 6—FULL REGULAR SERVICE TRAFFIC CAPACITY FOR E-60 BRIDGES BASED ON AN OVERLOAD OF 50 PER CENT.

Locomotives.	Weight.	Wheel Base.	Average Axle Load.	Percentage of Increase.†
Cooper's E-90	405,000	23.00	90,000	50.0
*Atlantic	336,000	31.79	98,800	57.0
Prairie	427,600	34.25	99,100	75.0
Consolidation	411,000	26.50	90,700	58.0
12-Wheel	413,500	27.08	87,600	58.0
Decapod	449,400	29.83	79,500	68.0
Pacific	450,000	35.20	98,000	67.0
Mikado	473,000	35.00	93,500	55.0
12-Wheel Articulated	523,800	30.66	87,100	56.0
10-Coupled	515,800	43.50	86,000	43.0
20-Wheel Articulated	754,800	59.80	85,000	58.0
16-Wheel Articulated	662,500	40.17	75,400	34.0
24-Wheel Articulated	834,000	65.92	74,400	35.0
12-Wheel Electric	552,000	38.50	94,600	84.0
16-Wheel Electric	619,200	44.22	77,400	94.0

*The Atlantic type applies to spans under 15 ft.; for greater spans the weight of this class of engine would run over 90 per cent. in excess of the heaviest type now in service.

†Percentages of increase in column 5 represent the approximate increase in weight of locomotives and driving-axle loads in excess of the maximum weights now in actual use.

It is less reasonable to assume that the still heavier types of Table 6 required for developing the full regular service capacity of an E-60 bridge will ever be operated even on high-grade divisions, unless gage of track is increased and greater clearances made, both laterally and vertically, in

tunnels and bridges and the right-of-way probably also increased, or, in other words, unless all present standards are abandoned and the railway practically reconstructed.

But suppose such types can be constructed and placed in operation without changing standard gage and clearances, they surely would not be operated regularly on low-grade divisions, and if their regular operations should be confined to high-grade divisions, then E-50 bridges on low-grade territory would have ample capacity to enable these types being transferred to and from these high-grade territories.

It appears, therefore, that an E-50 bridge is a good and economical type and provides for increased loading above the heaviest now in service to a sufficient extent to justify the railways which consider it a proper standard on all divisions until such time as conditions require practically a complete reconstruction of the railway.

It is, of course, admitted that an E-60 bridge is heavier, stronger and stiffer than an E-50 bridge. It will stand more abuse and more neglect, but it will cost from 12 per cent. to 15 per cent. more for its construction. While a number of roads have adopted this class of bridge for all divisions and others are contemplating its adoption, the justification therefor is not apparent in many cases. The mere fact that one or two roads started a somewhat radical change by building E-60 bridges should not in itself be sufficient excuse for other roads to do likewise, thereby apparently playing the youthful game of "follow your leader."

This tendency toward the adoption of E-60 loading is perhaps influenced more by precedent than by good, sound reason and judgment, and is being stimulated by the bridge companies, who profit by a greater tonnage of metal used in construction.

The writer hopes it will not be inferred that he condemns E-60 bridges as unreasonably heavy and extravagant and, therefore, not consistent with economical construction. They are better bridges than the E-50 class, and those who are in a position to justify them in paying more for the stronger structure, or who honestly believe this reserve strength will be required in the future, should not be classed with the extravagant, since at the most it is a case of foresight and judgment.

While E-60 bridges are stronger than those of E-50 class, it is probable that if the weights of engines ever increase to an extent sufficient to develop their capacity, many of these bridges, as now being constructed, will not have sufficient clearance to enable such excessively large locomotives to be safely operated. If, therefore, E-60 bridges are constructed, it would be well to provide a lateral clearance of at least 8 ft. from the center of track and an overhead clearance of not less than 25 ft. above top of rail, in which case there will be some possibility of operating over them the excessively large locomotives required to develop their strength.

Those roads which prefer stronger bridges on account of severe and heavy service on high grades could reasonably adopt the E-60 as standard for high-grade divisions and E-50 for low-grade divisions.

CONCLUSIONS.

Conclusions, as they appear to the writer, consistent with the foregoing investigation may be briefly summarized as follows:

(1) It is reasonable to assume that rolling loads of sufficient weight to develop the full regular service capacity of an E-50 bridge, as indicated in Table 5, will probably be operated regularly over heavy-grade divisions, but it is doubtful whether such types will ever be regularly operated over low-grade divisions.

(2) It is less reasonable to assume that rolling loads of the weights necessary for developing full service capacity of an E-60 bridge, as indicated in Table 6, will ever be operated even on high-grade divisions, unless present standards of gage, roadbed and clearances are abandoned and the road practically reconstructed.

(3) An E-50 American Railway Engineering Association Specification bridge is a good and economical type with sufficient strength to safely carry, in regular unrestricted service, the heaviest locomotives that can be safely operated without a possible complete revision of present standard clearances.

(4) An E160 bridg is heavier, stronger and stiffer than an E-50 bridge and its construction will cost from 12 per cent. to 15 per cent. more. It will safely carry the heaviest loads that it is possible to conceive of, but if the weight of engines ever increases sufficiently to develop its capacity, bridges as now constructed will probably not give sufficient clearance to enable such enormous locomotives to be safely operated.

(5) The tendency of railways is toward the adoption of E-60 bridges, but this in many cases appears to be influenced more by precedent than by good, sound reason and judgment, and it is stimulated by those who profit thereby on account of the greater tonnage of metal used in construction.

(6) If an E-60 bridge is considered warranted by the heaviest power likely to be operated, its proper place is on high-grade divisions, and it would, therefore, be good engineering practice to construct E-50 bridges on low-grade divisions, since they will have sufficient strength to permit the occasional operation to and from high-grade territories of the heaviest equipment which could be operated on the E-60 bridge in regular service traffic.

(7) E-60 bridges would be more consistent if constructed with greater clear width and height than sanctioned by present standards, because this would provide for probable increased width and height, as well as weight of the enormous rolling stock required to develop their capacity.

DISCUSSION.

C. D. Purdon, Chief Engineer, St. Louis Southwestern Railway:

The writer agrees with Mr. Greiner generally, and, indeed, had formed the same conclusions a long time ago and suggested them at a meeting of the American Society of Civil Engineers, held in St. Louis at the time of the Louisiana Purchase Exposition. The report of this meeting will be found in Vol. LIV, part A, Transactions, A. S. C. E.

The largest engine the writer has seen any account of is the Santa Fe double Mallet, which weighs 850,000 lbs. on a total wheel base of 108 ft. 1½ in.

The drivers are in two sets of five axles each; one set has 19 ft. 9 in. wheel base and weighs 275,000 lbs.; both combined have 49 ft. 11 in. wheel base and a weight of 550,000 lbs., while the engine alone has a weight of 616,000 lbs. on a wheel base of 66 ft. 5 in.

This engine would cause the same strain on spans of 10 to 100 ft. as Cooper's E-55 to E-63, adding from 10 to 25 per cent. to the strain caused by E-50.

Some engines that would class E-50, say on a span of 40 or 50 ft., or over, might, from heavy axle loads, class much higher on a span of 10 to 20 ft. For this reason the joint specifications of the Rock Island and the Frisco were gotten up, using the American Railway Engineering Association formula for impact $\frac{300}{L + 300}$, but adding an impact of $\frac{100 - L}{500}$ to spans under 100 ft.

The St. Louis Southwestern Railway now uses the specifications of the American Railway Engineering Association, with E-50 loading for trusses or girders and E-55 for stringers and floor beams and short girders.

The writer thinks that such an addition to Mr. Greiner's loading of E-50 would be desirable and probably sufficient.

John D. Isaacs, Consulting Engineer, Southern Pacific Company:

Like all productions of Mr. Greiner's pen, his discussion of rolling loads for bridges is of much interest and merits close study.

In general we agree with Mr. Greiner's conclusions, but the methods of computation adopted by the Harriman lines are somewhat different from those of the specifications of the American Railway Engineering Association, so that the tabulated relative stresses, etc., would differ in a comparison based upon our specifications.

Our specifications require all pointer systems to be so designed as to take care of 80 per cent. increase of live loads, and in view of the

low unit stresses used throughout, an increase of 80 per cent., without speed restrictions, would not be beyond safe practice on other members. As our present loads are equivalent to E-55, an increase of 80 per cent. would be equivalent to practically E-100. We, therefore, do not think we would be justified at present in increasing the live loads for which our bridges are now designed. At a recent conference of the Harriman Engineers this matter was fully discussed and this conclusion approved.

We agree with Mr. Greiner that a 50 per cent. increase rolling load, without speed restrictions, would be safe practice on bridges designed under American Railway Engineering Association specifications, but this percentage of increase could not safely be exceeded on bridges designed under ours.

As to using live load E-50 on low grade lines and E-60 on high grade lines, considering difference of speeds, the necessity of frequently operating the heaviest rolling stock over both high and low grade lines, and the advantage in cost and deliveries of minimizing the number of common standards, we think that all bridges on any given line, whether high or low grade, should be designed for the same live loads.

J. P. Snow, Consulting Engineer:

The writer fully concurs in the statement made by Mr. Greiner in regard to the practicability of overloading well-designed bridges; and does not even consider bridges to be unsatisfactory, so far as overstrain goes, until they are strained 50 per cent. in excess of the standard. In short, Mr. Greiner's position is conservative on the subject.

It is perhaps anomalous that we design bridges for a certain load and then say that the regular full service load is 50 per cent. or more greater. The practice is right, but the terms are, perhaps, unfortunate. The non-technical President may not understand the situation, but the Engineer should. Cooper's loadings are understood to designate the axle load and operating officials are frequently nervous when their engines of Atlantic types get heavier on axles than the loading used in designing their bridges.

Freight train loads per foot will probably be increased more than locomotives. Hundred-ton coal cars are now in sight. This means that our long-span bridges must be looked after, as these cars will make a load of at least 6,000 lbs. per foot.

The writer believes, with Mr. Greiner, that E-50 bridges will carry with reasonable safety anything that will be run on our present gage and clearances, and it is absurd to think of enlarging them. On the other hand, the writer believes our scheme of loading should be based on wheel spacing more consistent with actual practice than Cooper's series, so that a 50 loading, for instance, would more nearly represent a 50 engine.

H. Austill, Jr., Bridge Engineer, Mobile & Ohio Railroad:

Mr. Greiner's paper is certainly a timely and valuable contribution to engineering literature, and the writer heartily agrees with what he has to say.

Certainly locomotive designers must keep within the limits of the present standard gage and track and tunnel clearances. In the writer's opinion the center of gravity of future locomotives cannot be materially raised above that of the largest locomotives of to-day, nor can the width be materially increased.

Referring to Table 1 and omitting the articulated type and electric locomotives, the minimum weight of double-header (Atlantic) = 728,400 lbs., with wheel base equal 127.76 ft., weight per foot = 5,700 lbs., while the maximum (10 coupled) weighs 1,074,000 lbs., with wheel base = 161 ft., weight per foot 6,670 lbs., while the wheel base varies for double-headers from 127 ft. to 161 ft., and the weight per foot from 5,700 to 6,670 lbs. It is clear that the tendency is to increase the wheel base as the weight of engine is increased.

Thus, of the engines compared, the weight of engines is increased 47.4 per cent., while the wheel base is increased 42.5 per cent., and the weight per foot only 17 per cent.

It would have been interesting had the author included the wheel bases in Table 2.

Of course, the axle loads of recent locomotives are considerably heavier than those of some years ago, and on short spans the stresses are increased in much greater proportion than on longer spans.

It is evident that those roads that are designing for E-60 throughout are certain to get a bridge sufficiently strong to carry the loads that we may reasonably expect to be developed, but it is quite doubtful that an economical design will in all cases be secured; and when bridges are designed for E-60, it certainly would be well to increase the clearances now specified by the American Railway Engineering Association.

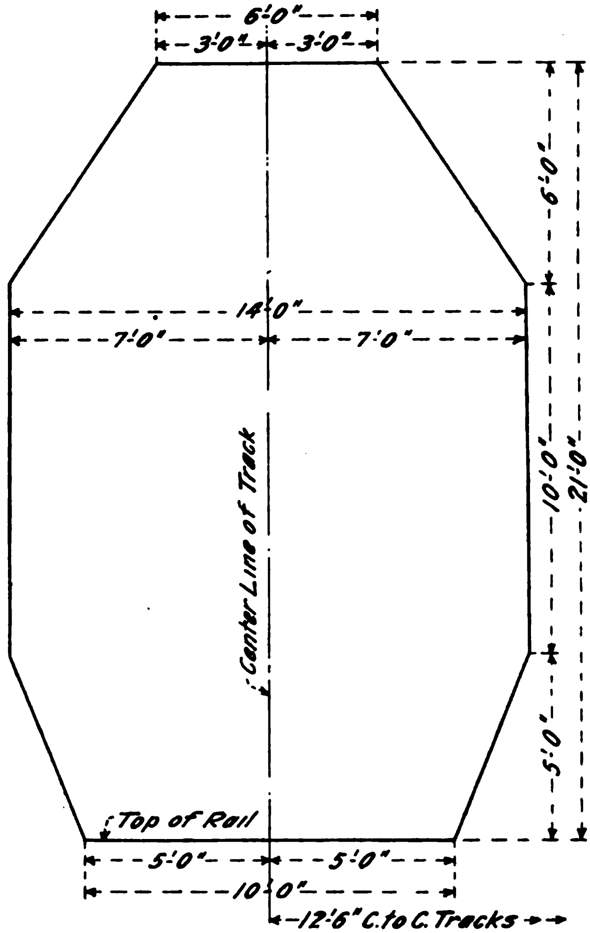
In view of the foregoing and data in Mr. Greiner's paper, it would seem to the writer quite proper to consider seriously the adoption of a standard system of loading similar to Cooper's series, but with increased axle spacing, or where Cooper's loading is used to design short spans, suspenders and floor systems for a higher class loading than truss members of longer spans. The writer's recent experience in calculating stresses from a 136-ton Mikado engine on bridges designed for E-45 loading seems to justify the latter method in some cases at least.

A. W. Buel, Consulting Engineer:

Probably the most important point raised in Mr. Greiner's paper is that of clearance, both lateral and vertical, and although he mentions this point in several places, both in the body of his paper and in the conclusions, it merits further consideration. The American Railway Engineering specifications (Manual of 1911) requires a vertical clearance of 22 ft. from top of rail, which is about one foot more than the

common practice of a few years ago, but retains the 7-ft. lateral clearance from center of track which has been standard for a great many years on Eastern roads.

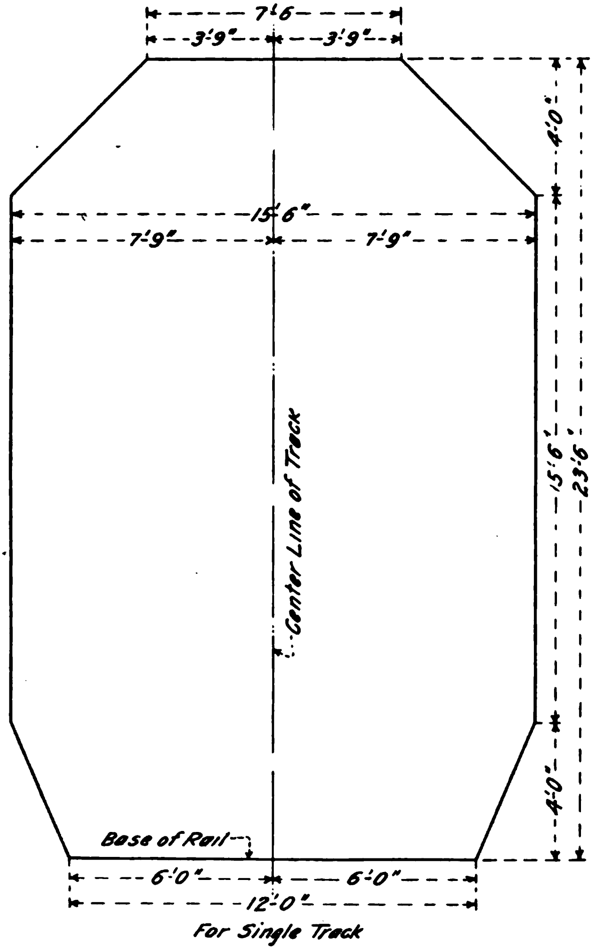
The clearance requirements of three specifications, written in 1903, 1906 and 1910, respectively, clearly indicate a tendency towards more



STANDARD CLEARANCE DIAGRAM, WESTERN MARYLAND RAILROAD, 1903 (USED WITH E-50 LOADING).

ample clearances, both with the E-50 and heavier loadings. The Western Maryland Railroad Company's specifications of 1903, with E-50 loading, called for a lateral clearance of 7 ft. and a vertical clearance of 21 ft. from top of rail, and 12 ft. 6 in. center to center of double tracks.

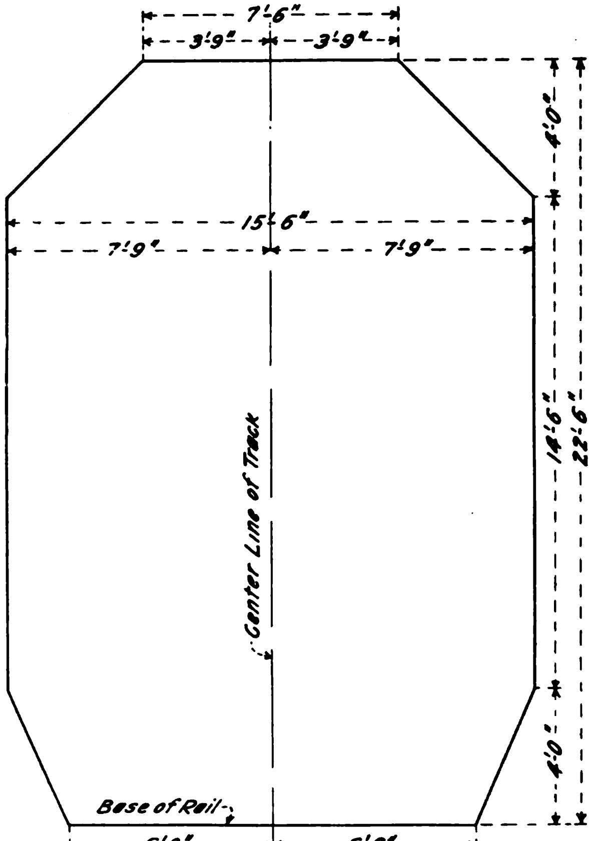
The Western Pacific Railway Company's specifications of 1906 required a lateral clearance of 7 ft. 9 in. and a vertical clearance of 23 ft. 6 in. from base of rail, the loading being also E-50. The Western Maryland Railway Company's specifications of 1910, with a loading of an articulated locomotive (2-8-8-2), weighing 488,000 lbs., followed by a tender



STANDARD CLEARANCE DIAGRAM, WESTERN PACIFIC RAILWAY, 1906 (USED WITH E-50 LOADING).

weighing 152,000 lbs., and a train load of 5,500 lbs. per foot of track (approximately equivalent to E-60), specified a lateral clearance of 7 ft. 9 in. and a vertical clearance of 22 ft. 6 in. from base of rail, with tracks 13 ft. centers.

The clearances required on Western roads are probably greater on the average than those on Eastern roads. Possibly the great expense that would be incurred in changing the clearances on an old road running through a thickly settled country accounts for this condition. It



STANDARD CLEARANCE DIAGRAM, WESTERN MARYLAND RAILROAD, 1910 (USED WITH LOADING OF 2-8-8-2 ARTICULATED LOCOMOTIVE, FOLLOWED BY 5,500 LBS. PER FT. OF TRACK; WEIGHT OF ENGINE, 488,000 LBS.; OF TENDER, 152,000 LBS.).

would be interesting to know how many of the fourteen roads that have adopted E-60 loading or heavier have also increased their lateral clearance to more than 7 ft., as there is not much room for doubting the

truth of the author's statement that the service capacity of E-60 bridges cannot be developed with the clearance generally in use. It is almost obvious that the lateral clearance should be between 7 ft. 6 in. and 8 ft. from center of track for all bridges designed for loadings over E-50.

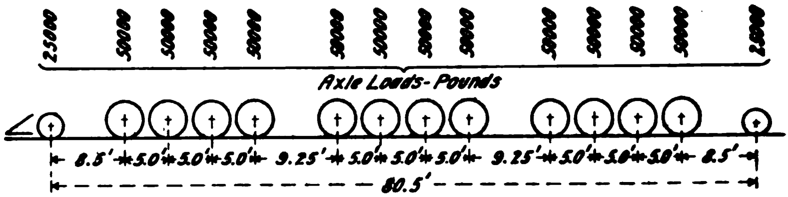
If the cost of increasing the clearances over an entire division should be too large a charge to incur, on account of tunnels, very large bridges or other limitations, it would then seem inconsistent to use a heavier loading than E-50 for such division. On the other hand, there are some cases, such as on new roads or new divisions and possibly on some divisions of old roads, where the cost of increasing the clearance would not be prohibitive, for which it may be advisable to adopt an E-60 loading or equivalent, provided the traffic, present and prospective, and the grades are such as to justify the heavier loading.

The author assumes and states that properly designed and constructed bridges will safely carry an overload of 50 per cent. without restrictions. Probably few, if any, would seriously disagree with this statement if it were limited to a proposition of expediency more or less temporary in nature. But apparently the author proposes that until the overload on a well-designed and constructed bridge exceeds 50 per cent. it may be considered as working under conditions for which it was designed. The writer has some doubt as to the life of some types of bridges under average conditions, when subjected to a 50 per cent. overload from regular service traffic and thinks that there would not be sufficient margin to provide for such "abuse and neglect" as is too often met with. With all the bridges on a road or division subjected to an overload of 50 per cent. under the regular service traffic, the conscientious Engineer in charge would be loaded with a great responsibility (more than a 50 per cent. overload), not desirable from any viewpoint, and if properly met the road would be loaded with an excessive cost of supervision and maintenance. If not properly met, the loss due to accidents might balance the account.

If the element of "guess" in our impact formulas is not further from the truth than is indicated by the still incomplete investigations of the subject, it is probable that a 50 per cent. overload would approach uncomfortably near the ultimate capacity of some members, particularly long columns. It is a fairly debatable question whether a 50 per cent. overload "without restrictions" should be considered entirely safe, in all cases, except as a temporary expedient or where the bridge could receive more than ordinary care and inspection.

But admitting, for the sake of argument, that the author's 50 per cent. overload proposition is conservatively safe (which the writer is not yet quite prepared to do), are we justified in assuming that the weight of locomotives and trains will not increase to a point excessive for E-50 bridges? Already G. R. Henderson, the noted Mechanical Engineer, Consulting Engineer for the Baldwin Locomotive Works, has proposed a triplex type (articulated) locomotive (2-8-8-8-2), weighing

650,000 lbs. on an 80 ft. 6 in. wheel base (63.5 ft. driving wheel base). This locomotive would produce a loading about equivalent to E-60, and it should not be surprising if the type were to be adopted for trial by some roads at an early date. The Henderson triplex locomotive, as proposed by Mr. Henderson, is to have axle loads of 50,000 lbs. If



TRIPLEX TYPE LOCOMOTIVE (2-8-8-8-2, WEIGHT, 650,000 LBS.) DESIGNED BY G. R. HENDERSON, CONSULTING ENGINEER, BALDWIN LOCOMOTIVE WORKS.

successful the same type would probably be built in the future with from 10 to 20 per cent. greater weight on drivers, which would run very close to what the author calls full regular service capacity for E-50 bridges. With such locomotives under contemplation for early operation, it does not seem to the writer that it is extravagant to design new bridges for E-60 loading where conditions justify the maximum, but he is in entire accord with the author that such bridges should be built with larger clearances than have been heretofore the common practice.

C. E. Smith, Assistant Chief Engineer, Missouri Pacific Railway:

For a number of years Engineers have been predicting that the limit in the weight of rolling stock would soon be reached. So persistent has been this prediction one is led to the belief that the wish was father to the thought. Just as persistently, however, the weights have reached and passed the predicted limits. An editorial comment in the Railroad and Engineering Journal of February, 1888, said:

"The fact that there are examples of passenger engines which weigh 100,000 lbs. or more leads to reflection and anticipation; how big will locomotives be in thirty years? Will this increase in weight continue and in the year 1918 will there be passenger engines running which weigh 200,000 lbs. or over?"

That weight of engine was reached in ten instead of thirty years, and it would not be surprising if in 1918 passenger engines weighing 400,000 lbs. are running.

In spite of the tremendous increase in weight in the past, however, many Engineers now believe that, in so far as the effects on bridges are concerned, the limits will be reached well within the capacity of bridges designed according to the best modern practice for Cooper's E-50. This conforms with the conclusion reached by Theodore Cooper many years

ago. When his loadings were first proposed—about 1895—loading E-40 was considered sufficient to cover all future increase, and it was adopted and used by many important roads. In 1899, after further study, Mr. Cooper recommended the adoption of his E-50 loading by an important road as being in his opinion sufficient to cover all future load developments.

The diagram showing increase in weight of locomotives indicates that the increase in weight was not very rapid during the first fifty years in which locomotives were built, at the expiration of which period the maximum weight, exclusive of tender, was 50 tons. Between 1880 and 1890 the rate of growth increased greatly, and following the introduction of the wide firebox about 1888 and the inauguration of the general use of steel tires and rails, the increase in rate of growth was marked.

In the decade between 1892, when the weight of the heaviest locomotive was about 70 tons, and 1902, when it reached 144 tons, the increase in weight was in excess of 100 per cent. During the last decade the weight increased from 144 tons in 1902 to 190 tons in 1912, an increase of only 30 per cent. (not including the Mallets, which the writer prefers to consider a modified form of double-header). It will be seen that the rate of increase was much less during the last decade than during the preceding one, which would appear to indicate that, for ordinary types of locomotives other than Mallets, the increase in weight will be less rapid in future, which conclusion is also indicated by a number of other conditions.

The increase in axle load has not been so rapid nor so great as the increase in total weight, as the greater weight has usually been spread out over a greater number of axles.

The increase in weight, therefore, has been accompanied by a great increase in length, so that the weight per linear foot of engine has not increased anywhere near so rapidly nor so much as the total weight, which would indicate that even during the last decade the increase per foot has been slight. The increase in total weight with relation to the effect on bridges should not be compared on a percentage basis, but should be considered only in connection with the length of locomotive and preferably with reference to the relative stresses caused by the different loads. Such a comparison is well illustrated in Mr. Greiner's paper, where it is shown that the Santa Fe locomotive, which weighs 174 per cent. more than a single Cooper's E-50 locomotive, causes stresses only from 15 to 33 per cent. greater; the 16-wheel Mallet, which weighs 119 per cent. more, causes stresses from 26 to 34 per cent. greater; the 20-wheel Mallet, which weighs 112 per cent. more, causes stresses 1 to 14 per cent. greater; the Pacific, which weighs 20 per cent. more, causes stresses from 7 per cent. less to 8 per cent. more; and the Mikado, which weighs 36 per cent. more, causes stresses from 2 to 16 per cent. more.

It does not follow that the stresses in a bridge designed for Cooper's E-50 would be increased in all members by the percentages given above,

nor do those percentages represent in any case the amount a bridge would be overloaded by the respective locomotives.

The term "overloaded" as applied to a bridge is ambiguous, inasmuch as each member gets a different "overload" when the load is increased over that used in the design. The term is logical and consistent then only when applied to individual members, and then only when analyzed along the same lines as those along which the bridge was designed.

For example, if a bridge were designed for a one-hundred-ton locomotive, it would not be proper to say that it would be "overloaded" 50 per cent. by a locomotive weighing 150 tons. If the heavier locomotive had the same arrangement and spacing of wheels and also the same distribution of load, then the amount of "overload" for the bridge as a whole could be approximately stated. In certain members, however, the amount of "overload" would be greater, while in others it would be less than the percentage indicated by a direct comparison of the weights.

As an illustration, a Pratt truss span 200 ft. long, composed of 8 panels 25 ft. long, will be considered with reference to increase in load, assuming that the bridge was designed for Cooper's E-40 and later subjected to a loading equivalent to Cooper's E-60, that is, 50 per cent. heavier. The weight of the structure will be taken as 2,000 lbs. and of the track 400 lbs. per linear foot. Full impact allowances will be made and the entire dead weight will be assumed as applied at the bottom chord.

The dead load stresses, live load stresses, impact allowances and total stresses for the Cooper's E-40 and E-60 loadings are given for the different members in the table. The right-hand column of the table gives the percentage of increase in stress in each member due to the increase in live load.

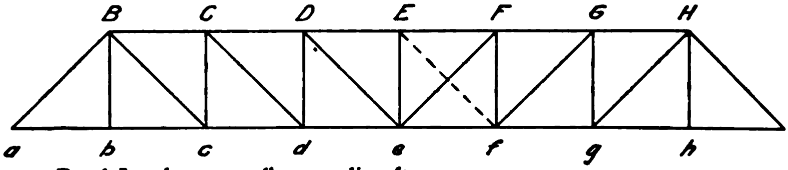
Comparison between increase in live load and resulting increase in the stresses in the various members:

STRESSES IN THOUSANDS OF POUNDS

Member	Dead Load	Cooper's E-40	Impact		Total	Dead Load	Cooper's E-60	Impact		Total	Increase %
			Per Cent.	Amt.				Per Cent.	Amt.		
ab	87.5	181.0	60.0	108.6	377.1	87.5	271.5	60.0	162.9	521.9	38
bc	87.5	181.0	60.0	108.6	377.1	87.5	271.5	60.0	162.9	521.9	38
cd	150.0	299.8	60.0	180.0	629.8	150.0	449.8	60.0	269.9	869.7	38
de	187.5	373.6	60.0	224.2	785.3	187.5	560.4	60.0	336.2	1084.1	38
aB	136.7	282.4	60.0	169.4	588.5	136.7	423.5	60.0	254.1	814.3	38
BC	150.0	299.8	60.0	180.0	629.8	150.0	449.8	60.0	269.9	869.7	38
CD	187.5	373.6	60.0	224.2	785.3	187.5	560.4	60.0	336.2	1084.1	38
DE	200.0	395.2	60.0	237.1	832.3	200.0	592.8	60.0	355.7	1148.5	38
Bb	30.0	75.6	85.7	64.8	170.4	30.0	113.5	85.7	97.3	240.8	41
Cc	45.0	118.0	70.6	83.3	246.3	45.0	177.0	70.6	125.0	347.0	41
Dd	15.0	78.4	75.0	58.8	152.2	15.0	117.6	75.0	88.2	220.8	45
Ee	0.0	45.1	80.0	36.1	81.2	0.0	67.7	80.0	54.2	121.9	50
Bc	97.6	213.1	66.7	142.1	452.8	97.6	319.6	66.7	213.1	630.3	39
Cd	58.6	153.4	70.6	108.3	320.3	58.6	230.1	70.6	162.5	451.2	41
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

COUNTER STRESSES (SHEARS)

Member	Dead Load	Cooper's E-40	Impact		Total	Dead Load	Cooper's E-60	Impact		Total	Increase %
			Per Cent.	Amt.				Per Cent.	Amt.		
Panel											
ef	—15.0	45.1	80.0	36.1	66.2	-15.0	67.7	80.0	54.2	106.9	61
fg	—45.0	21.5	85.7	18.4	—6.1	-45.0	32.2	85.7	27.6	+14.8	..
gh	—75.0	5.5	92.3	5.1	—64.4	-75.0	8.2	92.3	7.6	—59.2	..
FLOOR MEMBERS											
(Stringer) (Moment)	31.3	30.5	92.3	281.5	617.8	31.3	457.5	92.3	422.3	911.1	47
Floor Beam Load	13.0	75.6	85.7	64.8	153.4	13.0	113.5	85.7	97.3	223.8	46



Dead Load $=$ 2,400 lbs. per lin. ft.

Live Load $=$ Cooper's E-40 and Cooper's E-60.

$$\text{Impact} = \frac{300}{L + 300}.$$

The increase in stress ranges from 38 per cent. for the chords and end posts to 61 per cent. for the counter in the panel next to the center, and the increase in load calls for a counter in panel *fg*, which was unnecessary for the lighter loading. If the unit stress used in the design had been 16,000 lbs. per sq. in., the unit stresses in the "overloaded" truss would run from $1.38 \times 16{,}000 = 22{,}100$ lbs. per sq. in. for the chords, to $1.61 \times 16{,}000 = 25{,}800$ lbs. per sq. in. for the counter. That is, the limiting stress occurs in a member which could have been made stronger in the original design at practically no additional cost. The arrangement of the members and details is frequently such that it is difficult, at any reasonable expense, to satisfactorily reinforce the weak counter. The result in the past has been that light counters and absence of counters, together with light web members near the center of the span, have caused the condemnation and taking down of many bridges in which the remaining members could have withstood greater stresses. This is unfortunate, because the light members at the center of a span constitute such a small portion of the total weight of the structure.

Some method of design should be used that will result in bridges at least as well built as the Deacon's one-hoss shay, in which no part was stronger than the rest.

Now that a practical agreement has been reached as to the proper maximum unit stresses in an old bridge, it would appear consistent and logical to so arrange the design that this maximum unit stress would be reached in all members under the same ultimate live load.

For example, it has been stated that in a bridge designed for a unit stress of 16,000 lbs. per sq. in., the maximum unit stress allowable under increase in load would be 26,000 lbs. per sq. in., an increase of 62.5 per cent. It has also been shown that an increase of 50 per cent. in the live load causes the total stresses in the great majority of the members in the case under consideration to increase but 38 per cent. What percentage of increase in live load then will cause the unit stresses to increase 62.5 per cent? The difference between the percentage of increase in live load and in total stress in any member is due to the dead load stress remaining constant. Then the permissible increase in the live load will depend upon the relation of the dead load to the original live load.

Let the total stress in any member as designed be 100 per cent., of which the dead load stress is D and the live load stress, including impact, is L per cent. Then

$$D + L = 100.$$

Let KL represent the increase in live load, which, when added to the total stress used in the design will increase the latter 62.5 per cent. Then

$$D + L + KL = 162.5$$

$$K = \frac{162.5 - D}{L} - 1$$

Since the percentage of increase in all the chord members is so nearly constant, the center moments due to dead and live load may be used in the comparison for the chords.

The dead load moment $D = 6{,}000$, or 33.6 per cent.

The live load moment $L = 11{,}856.5$, or 66.4 per cent.

Then $K = \dfrac{162.5 - 33.6}{66.4} - 1 = 1.941 - 1 = 0.941.$

That is, under the conditions assumed above, the live load must increase 94.1 per cent. before the maximum limit of 26,000 lbs. per sq. in. is reached in the chords and end posts.

In order that all parts of a bridge may reach the maximum allowable stress under the same live load, there might be a clause in bridge specifications about as follows: "All parts shall be so designed that an increase of 100 K per cent. in the live load will not cause the unit stresses to exceed those specified by more than 62.5 per cent.; K shall be determined from the formula $K = \dfrac{162.5 - D}{L} - 1$, in which D and L are the percentages of dead and live load center moments used in the design."

Theoretically the value of K should be determined from D and L for each member designed, including floor members. Different values would be obtained for different members, the lowest for the counters and the highest for the chords and end posts. For the greatest efficiency, then, the greatest value of K—usually found from chord stresses—would be used in revising the design to provide for "overload."

The above method of design would be somewhat objectionable on account of the amount of work involved; its justification would be the consistent strength under the greatest load. The present method of designing is open to the objection that the bridge is not of uniform strength under any load heavier than that for which it is designed. It seems unnecessary to put into the chords a great mass of metal that can never be used up to its safe limit.

A simpler and apparently satisfactory method would be to *use the maximum allowable stresses in the design, together with a loading sufficiently heavy to cover all future load developments.* There would be a simple change in terminology; what is now looked upon as "overload" would in such a design be looked upon as "development toward the ultimate live load." The difficulty here would be in the choice of a sufficiently heavy live load, because no heavier load than that assumed could ever be allowed upon any bridge designed in this manner.

Since the present loadings and unit stresses, arbitrarily chosen, result in bridges of inconsistent strength, there is good reason why other more consistent loadings and stresses should be chosen.

The great discrepancies between the percentages of increase in weights of actual locomotives over Cooper's E-50 and the percentages of increase in the corresponding stresses, as mentioned above, indicate that Cooper's loadings do not well represent modern locomotives, however well they might have represented them at the time Cooper's loadings were evolved.

That Cooper's loadings do not well represent present heavy engines is further indicated by the diagram comparing Cooper's E-50 with heavy Pacific, Mikado and Mallet type locomotives. The very short length and lighter weight of Cooper's E-50 loading is apparent at a glance. Cooper's E-50 and E-60 diagrams are, in a measure, absurdities, since no locomotive has ever been built, nor probably ever will be, that corresponds with those loadings.

It would appear then that more consistent results could be obtained by the use of some loading that would more correctly represent present and future heavy engines. The uselessness of choosing any particular combination of axle loads appears to be indicated by past experiences along those lines when many loadings were chosen.

On account of the great number of special loadings in use in the early days, the labors of calculation were greatly increased, especially to bridge companies and Consulting Engineers who were compelled to make use of a number of the loadings. There was much agitation for standard loadings on the one hand and for equivalent uniform loads on the other.

In 1892 Dr. J. A. L. Waddell made a canvass of a large number of Engineers whose opinions were worth having, with the following result:

82 per cent. favored the use of equivalent uniform loads;

18 per cent. favored continuing the use of concentrated loads.

The principal difficulty that followed arose from the fact that Engineers could not for some time be brought to agreement as to what

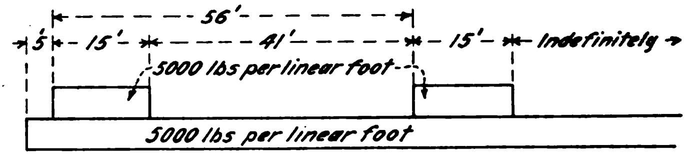
loading the proposed equivalent load should be made equivalent to, and when a few years later, practical agreement was reached in Cooper's loadings, enabling the use of standard moment and shear tables, thereby reducing the labors of calculation immeasurably, the necessity for the equivalent uniform loading became less noticeable and the agitation passed away to a large extent.

The loadings attained such great popularity that a large number of railroads used them even in turntable design, to which, on account of their short wheel base, they are entirely unsuited.

It would appear, in view of recent development in locomotive design, resulting in a great increase in length not foreseen by Mr. Cooper, a different loading should be used. The accuracy claimed for stresses calculated from concentrated loads is largely artificial, as the accuracy relates only to loadings that never cross bridges. That is, bridges are being built of uniform strength with relation to an impossible loading only; for actual loads in use now or in future some part will be stressed to its safe limit while there is yet a considerable margin in other parts. This results in a very uneconomical design, in that some parts must be disposed of before they have served their full usefulness because they are found in bad company.

For the reasons set out above the writer feels that Cooper's loadings are no longer suitable for bridge design, and that on account of the great diversity in axle spacing of present heavy locomotives there is no combination of concentrated loads that will give results nearer to actual stresses for all conditions than a properly chosen equivalent uniform load with excesses.

Cooper's E-50 can be represented by a uniform loading increased in two places (each the length of a driver wheel base and the length of one engine apart) to represent the excess weight on the drivers as follows:

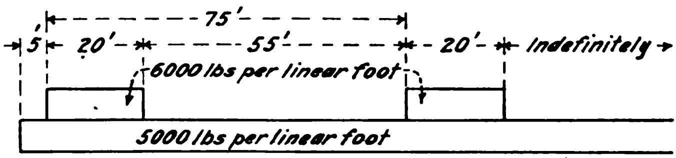


In view of the fact that the labors of calculation for Cooper's loadings have been simplified by the many tables that have been prepared, there may be no demand for an equivalent uniform load to replace Cooper's loadings, but it may well be that ease of calculation has delayed their abandonment and the choice of a more consistent loading.

Such a loading can be used in calculation with only a small portion of the labor involved in the use of concentrated axle loads. The stresses calculated for the above uniform loading are less than 2 per cent. smaller than those calculated for the corresponding concentrated loads for spans over 100 ft. For shorter spans the difference is somewhat greater, being 6 per cent. less for a span of 50 ft.

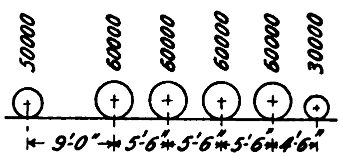
It is well known that the maximum bending moment or shear on a span caused by a single concentrated load is twice that caused by the same load uniformly distributed, and the moment or shear caused by a series of concentrated loads is greater than that caused by the same loads when distributed. In the present case the difference has been stated as 6 per cent. on 50-ft. spans. As the rails and top flanges under the ties do in reality distribute the wheel loads, the stresses calculated on the assumption that they are applied at knife edges are incorrect and larger than actual stresses, which indicates that those calculated from the uniform loading are more nearly correct. On very short spans the difference is greater and would become 50 per cent. on a 5-ft. span, but to realize the lower stress the uniform distribution of the load would require to be perfect, which perfection does not obtain in practice, thus necessitating the use of concentrated loads on short spans.

Instead of superseding Cooper's loadings by another set of concentrated loads to represent a modern type of heavy locomotive, such as the Pacific or Mountain or Mikado, it would seem preferable to choose a type of uniform loading closely approximating all those locomotives. Such a loading approximately equivalent to the Pacific and Mikado shown in the diagram would be as follows:



For lines on which it is reasonably certain the Mallets will be used a modified form of equivalent uniform load to represent such locomotives may be used.

To secure greater accuracy in the design of short spans, floor stringers, floor connections, etc., the writer would recommend the use of concentrated loads about as follows:



On account of the lack of knowledge of the exact amount of stress caused in any member by impact, the stresses indicated by calculations are fictitious. As the formula for impact in general use $I = \frac{300}{L+300}$ gives percentages that are higher than those invariably recorded in practical tests, the actual stresses are invariably much lower than the calculated stresses. A considerable reduction might be made in the

impact allowances, especially on long spans, with perfect safety, and the writer believes this may occur in future, in which case much metal now put in bridges to provide for impact will be considered available for resisting increased static stresses.

The maximum stress in any member of a single track bridge can, as a rule, occur but once during the passage of a train; in a double track bridge the combination of loads assumed in design seldom, *if ever,* occurs; in either case such maximum stress would occur for an instant only, during which it would be permissible to allow the stresses indicated by calculation to exceed those ordinarily allowed.

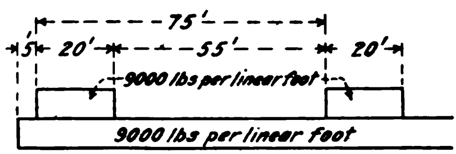
The use of electric locomotives will be greatly extended within the life of bridges now being built and it is possible there may be further development of the balanced locomotive. In either case there will result a great decrease in impact, and some of the metal formerly necessary to resist impact will then be available for increased static stresses.

Great difficulty has been experienced in the shipment of recent heavy locomotives in finding routes over which the clearances were sufficint and many of the obstructions are of such a nature that they can be considered practically permanent. This difficulty further indicates that future increases in weight must be accompanied by corresponding increases in length, the weight per foot to increase but little. The trend in this direction is indicated by the recently suggested Henderson triplex locomotive resting on 24 drivers run by three separate engines. The accompanying diagram shows the curves of bending moments of such an engine followed by tender and a train of the new Norfolk & Western 100-ton capacity coal cars, compared with Cooper's E-50. It can be readily seen that such traffic can use bridges designed for E-50 with entire safety and no restrictions.

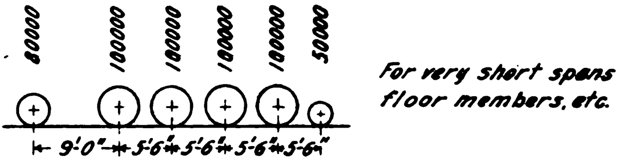
Maintenance difficulties in track and equipment will further delay and may prevent unlimited increase in weight per foot.

The facts stated above, among others, have convinced the writer that bridges built for Cooper's E-50 loading, according to the specifications of this Association (impact $= \dfrac{300}{L + 300}$ and basis of 16,000 lbs. per sq. in.), are sufficiently strong to carry without restrictions any loads that may ever come on them and that no heavier bridges are necessary. He believes, however, that at slightly increased cost much more consistent bridges, having greatly increased strength, can be obtained through the use of more logical loading and unit stresses in the design.

The writer suggests the use in design of an "Ultimate Rolling Load" as follows:

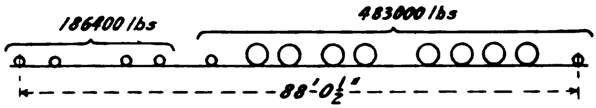


For all spans except very short spans, floor members, etc.

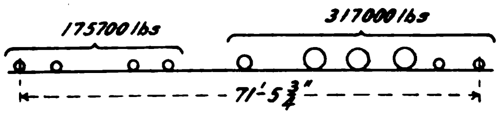


to which impact is to be added by the formula $I = \frac{300}{L + 300}$ and with unit stresses 62.5 per cent. higher than those contained in the railroad bridge specifications of this Association, which will give a unit stress of 26,000 lbs. per sq. in. for tension, other stresses to be increased in the same proportion.

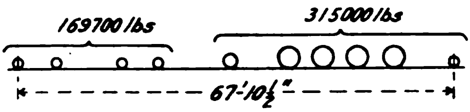
Detailed calculation will indicate that bridges designed for these suggested loadings and stresses will correspond closely with present E-55 designs for short spans and E-50 for long spans.



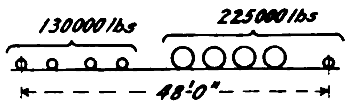
MALLET TYPE.



PACIFIC TYPE.



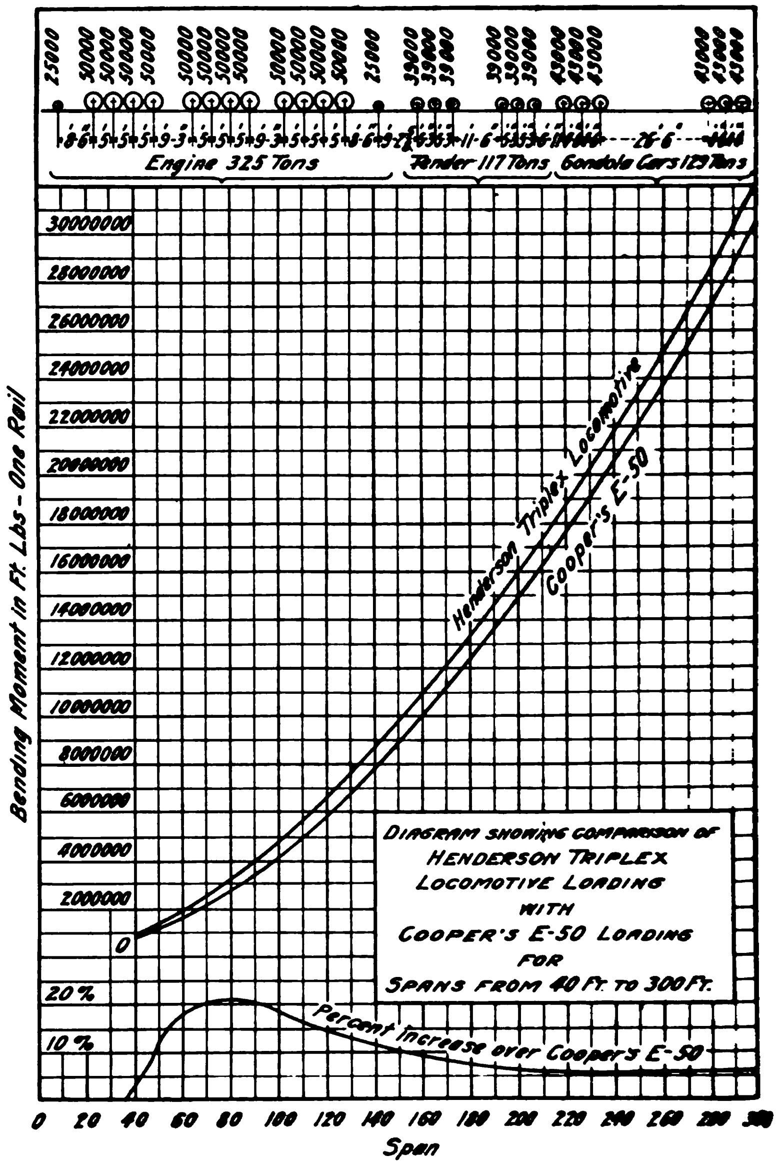
MIKADO TYPE.



COOPER'S E-50.

DIAGRAMS SHOWING COMPARISON BETWEEN COOPER'S E-50 AND ACTUAL HEAVY LOCOMOTIVES.

The suggested loadings may seem unreasonably heavy, but most bridges now being built will carry such a loading safely. The use of the suggested method of design will result in bridges of more consistent strength having less weight and at less cost than bridges of equivalent maximum strength designed according to present methods.


Engine 325 Tons
Tender 117 Tons
Gondola Cars 129 Tons
Bending Moment in Ft. Lbs - One Rail
Henderson Triplex Locomotive
Cooper's E-50
Percent Increase over Cooper's E-50
Diagram showing comparison of Henderson Triplex Locomotive Loading with Cooper's E-50 Loading for Spans from 40 Ft. to 300 Ft.
Span

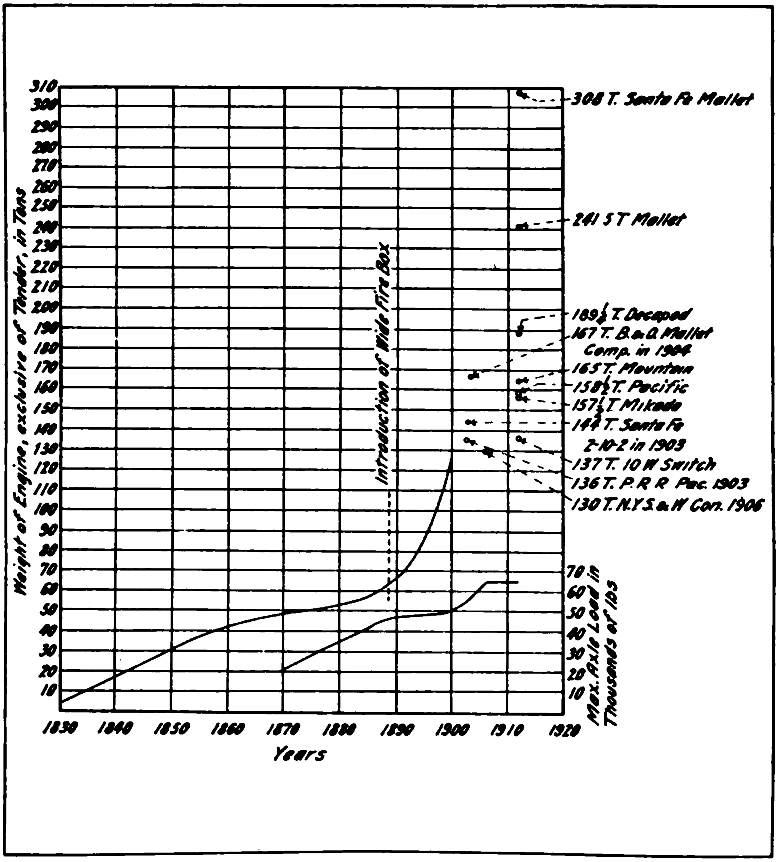


DIAGRAM SHOWING INCREASE IN WEIGHT OF LOCOMOTIVES.

COMMENTS BY THE AUTHOR.

J. E. Greiner, Consulting Engineer:

The discussion on Rolling Loads on Bridges and the conclusions contained therein were submitted merely as an expression of opinion with the hope of obtaining personal views from those experienced in the subject dealt with. It is very gratifying that so many experienced Engineers have stated where they stand. Some of these Engineers endorse the author's conclusions, and some do not. Since, after all, the whole subject is one based on judgment, the author is content to stand on the conclusions expressed in his original discussion.

EXPERIMENT WITH TREATED CROSS-TIES, WOOD SCREWS, AND THIOLLIER HELICAL LININGS.

Introduction by W. C. Cushing,
Chief Engineer Maintenance of Way, Southwest System, Pennsylvania Lines West of Pittsburgh.

In the Railway Age Gazette for June 5, 1908, page 24, the writer discussed "The Life of Steel Ties," and pointed out the necessity of solving the problem of control of refrigerator drippings before it would be possible to consider the wholesale use of steel cross-ties.

The experiments described in the following pages by those who had direct charge of the work, Messrs. Wiggins and McKeon, were undertaken by the writer to determine if it would be possible to find suitable rail fastenings which would enable us to obtain the full life of a preserved cross-tie until it should perish by decay. He was fully impressed with the short life of steel products used in track work, especially on railroads carrying a large amount of refrigerator traffic, and also with the idea that it might not be possible to obtain the full life of preserved cross-ties, because it seemed quite doubtful whether the fastenings heretofore proposed would last sufficiently long for the purpose. His suspicions against the much-heralded screw spike were aroused by the mere fact that it was already necessary in Europe to invent various methods of repairs, such as the wooden screw plug, the Collet wooden screw trenail, the Thiollier helical lining, and the Lakhovsky cast steel linings, and he called attention to this several years ago in the Proceedings of the Association, referred to by Mr. McKeon in his portion of the report.

The methods used in placing these screw spikes were those in common use in France, and the screw spikes used were obtained from France, as explained by Mr. Wiggins.

The trial shows that the screw spikes were too small, the method of placing—without shoulder support for the head—defective, and the problem of rust is still so serious that such kinds of fastenings are rendered ineffective in altogether too short a time.

As a result of these tests, more elaborate tests have been inaugurated on the Pennsylvania Railroad and on the Northwest System of the Pennsylvania Lines West of Pittsburgh, which are under the charge of a joint committee of the Lines East and West. The screw spike used is much larger, and is the result of the study made by the writer in the Association Proceedings referred to above. Some of the same difficulties are arising in the new tests, which clearly show that a screw spike is not a successful device for securing rails to wooden ties, unless

a successful method of repairs from time to time can be devised, which will enable one to "cure" the screw spike when it becomes loose, which it does inevitably in the course of time in many instances, under heavy traffic and severe conditions.

Indeed, it may be found ultimately that the Great Western Railway of England practice, of using bolts clear through the ties, may be the most successful plan.

Final judgment is, however, reserved for the completion of the tests now being conducted.

EXPERIMENT WITH TREATED CROSS-TIES, WOOD SCREWS AND THIOLLIER HELICAL LININGS AT SCIO, OHIO.

By R. D. McKeon, Assistant Division Engineer, Vandalia Railroad, Michigan Division.

The General Manager, under date of November 10, 1905, authorized the Chief Engineer Maintenance of Way, to make an experiment with wood screws and Thiollier's helical linings on the Pittsburgh Division of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway for the purpose of determining whether such a rail fastening was a proper one for use with treated ties in order to keep the ties in service for the full life given by the treatment, instead of having them destroyed before that time by spiking with the hook spike commonly used.

During the months from June to November, 1907, inclusive, the fastenings were installed on the eastward main track between mileposts 76 and 78, west of Scio, Ohio. The timbers used in the experiment were Kentucky short-leaf pine and red oak, treated with two and one-half gallons of creosote per tie, or 0.33 gallon per cubic foot of timber.

The description and details of the installation are given in Appendix A.

After an inspection of the track by the Chief Engineer Maintenance of Way, Division Engineer and Supervisor in February, 1913, it was decided that the track would have to be gaged at once, for it had become as wide in places as it should be allowed to go, and since common spikes would have to be used in the gaging, the experiment would be brought to a close and a final report prepared.

REASONS FOR DISCONTINUANCE OF THE EXPERIMENT.

(1) The screw spikes were not large enough, and the plan of placing them was not sufficiently good to furnish enough lateral resistance to prevent the widening of the gage. No device for adjustment was provided.

(2) The tie plates were almost entirely destroyed by rust, and many of the screw spikes and Thiollier linings were badly corroded, so that their holding power was destroyed (see photographs). This condition is

supposed to be aggravated by brine drippings from refrigerator cars. This traffic is large over this eastbound track.

(3) The holding power of screw spikes is greater than that of the hook spikes commonly used, but the forces tending to loosen them are very great, unless the surface of the track is kept in a high state of perfection. The spikes in loose ties are apt to be quickly loosened by having the threads in the wood destroyed.

(4) The above defects having developed in five and one-half years, it is plain that the fastenings must be adapted for repair work, or the full term of life for creosoted ties cannot be obtained.

It is impossible to extract the defective Thiollier linings or to introduce new spikes with good results, therefore the Lakhovsky linings were introduced at the joints in new holes, to compare them with the Thiollier linings (see description). Other devices, such as the square wood plug, and the Collet screw trenail of wood have been introduced in Europe for the same purpose, but were not tried in this experiment. The invention of these devices is proof that the same necessities for repairs exist in Europe as in this country (see Proceedings American Railway Engineering and Maintenance of Way Association, Vol. 10, Part 2, 1909, page 1464, "The Question of Screw Fastenings to Secure Rails to Ties"), and until that question is successfully solved, screw spikes cannot be a successful device for fastening rails to ties.

THE FOLLOWING CONCLUSIONS WERE ALSO DERIVED:

(1) The screw spikes offer a greater resistance to extraction than common spikes.

(2) Screw spikes will remain tight for a longer period than common spikes if the track is well maintained.

(3) By reason of greater holding resistance they tend to reduce creeping of rail and also to prevent the slewing of the ties, but this action is not complete and entirely satisfactory.

(4) The screw spikes do not cause the ties to split, as do the common spikes, on account of boring the holes in advance.

(5) The cost of maintenance of track for screw spikes is from two to four times as great as for common spikes, up to the time of discontinuing the experiment.

(6) Screw spikes cost from two to three times as much to apply as common spikes, and first cost is considerably greater.

(7) When screw spikes break, it is impossible to extract the stump from the hole, and when tie plates are used, it is either impossible or very costly to exchange the tie plates, so as to allow the proper number of spikes to be used. This can be a very serious matter when the spikes are cut off by a derailment.

(8) It is impossible to gage the track which is laid with screw spikes or to straighten rail which is canting on curves, when placed in accordance with the plan used for this experiment.

(9) It is impossible to remove screw spikes which have rusted, in order to replace them with new ones.

(10) The tie plates used in the test did not reinforce the head against lateral thrust and the under side of the spike head was flat and did not fit the base of the rail. Tie plates with bosses supporting the heads of the spikes and screws with heads beveled to fit the rail would decrease the lateral thrust and would offer a greater resistance to the rail creeping.

(11) Larger tie plates are required, as those which were used cut into the ties badly.

(12) It would seem desirable to fasten the tie plates to the tie with screw or common spikes so that the sawing action of the plate, under traffic, would be eliminated and reduce the cutting of the plate into the tie. The plate must be held firmly to the tie.

(13) The screws used in the experiment were too light. Heavier screws are needed, and two screws per rail on the inside should be used on curves to prevent canting and assist in maintaining the gage.

(14) The screws should be applied by some mechanical device, so that each screw would bear equally against the rail. By applying screws by hand, equal bearing on all spikes is not obtained.

(15) Some method should be devised to overcome the effect of the brine from refrigerator cars on track fastenings. The failure of these fastenings was due largely to the rusting of tie plates and screws.

COST OF SURFACING TRACK.

The cost of surfacing track on which the various combinations of fastenings were used varies from 33.32, cents per foot of track for groups 4 and 6, to 12.11 cents per foot of track for group 3. This difference is no doubt due to a large extent to the conditions under which the fastenings are used, rather than the fastenings themselves, groups 4 and 6 being located on curved track, while all the other groups are on tangent track. The cost of surfacing track on groups 2 and 3 varies from 12.11 cents on group 3, to 20.45 cents on group 2. These two groups are identical as to fastenings, but group 3 was used with oak ties, and group 2 used with pine ties, both of which were laid on tangent track. Groups 1 and 5 (pine ties) cost 15.02 cents for surfacing, while group 7 (oak ties) cost 16.51 cents, both being laid on tangent track.

COST OF LINING TRACKS.

The cost of lining track varies from 0.81 cent to 4.93 cents per foot of track; the highest cost being on group 3, on which group cost of surfacing was lowest. The cost of lining on groups 4 and 6 (oak ties) which are on curved track, is 3.72 cents per foot of track, while the cost of lining on groups 1 and 5 (pine ties) on tangent track is 4.83 cents per foot of track, both having the same combinations of fastenings.

COST OF GAGING TRACKS.

The cost of gaging varies from 0.26 cent on group 2, to 0.93 cent on groups 4 and 6. As very little gaging with screw spikes, and the fact that the track laid with screw spikes required gaging before the experiment was closed, would seem to indicate that the figures showing cost of gaging are of little interest.

COST OF TIGHTENING RAIL FASTENINGS.

The cost of tightening rail fastenings is fairly uniform for all the various groups, except group 3. As this group of ties was laid with common spikes and is located on curved track, it shows that the screw spikes on curves can be kept tight at much less cost than the common type. The screws laid with tie plates were maintained at less cost than those laid without tie plates, but there is a question as to whether the screws with the tie plates were kept as tight as those without tie plates. In many cases the tie plates rusted so badly that the rail, when a train passed over it, would be deflected quite a distance from the head of the screws. This was not the case in the track laid with the screws and no tie plates, as this track was very rigid, ties and rails were firmly against each other while the train passed over them. Cost of tightening the common spikes on tangent track is practically the same for the pine and oak ties, and slightly greater for groups 4 and 6 (oak ties) and groups 1 and 5 (pine ties), and less than group 7.

COST OF RENEWING RAIL FASTENINGS.

The cost of renewing rail fastenings is quite high, due to the fact that all the joint fastenings were renewed in 1910 with heavier screws and tie plates, improved joint fastenings and Lakhovsky linings, the original fastenings being too light; the creeping of the rail caused the heads of the screws to be sheared off.

TOTAL COST OF LABOR.

The cost of labor, groups 4 and 6, located on curved track, was largely in excess of all other groups, the excess being in the item of surfacing. This may have been caused by the curved track.

GRAND TOTAL COST OF LABOR AND MATERIAL.

This indicates that the cost of maintaining track laid with screw spikes costs from three to four times as much as track laid with common spikes. As the figures for the screw spikes contain the cost of work made necessary by the renewal of all joint material, screws, plates, etc., it does not seem that a fair comparison can be made between the two classes of fastenings, although the figures would indicate that, disregarding this feature, screw spikes are much more expensive to maintain than the common spikes.

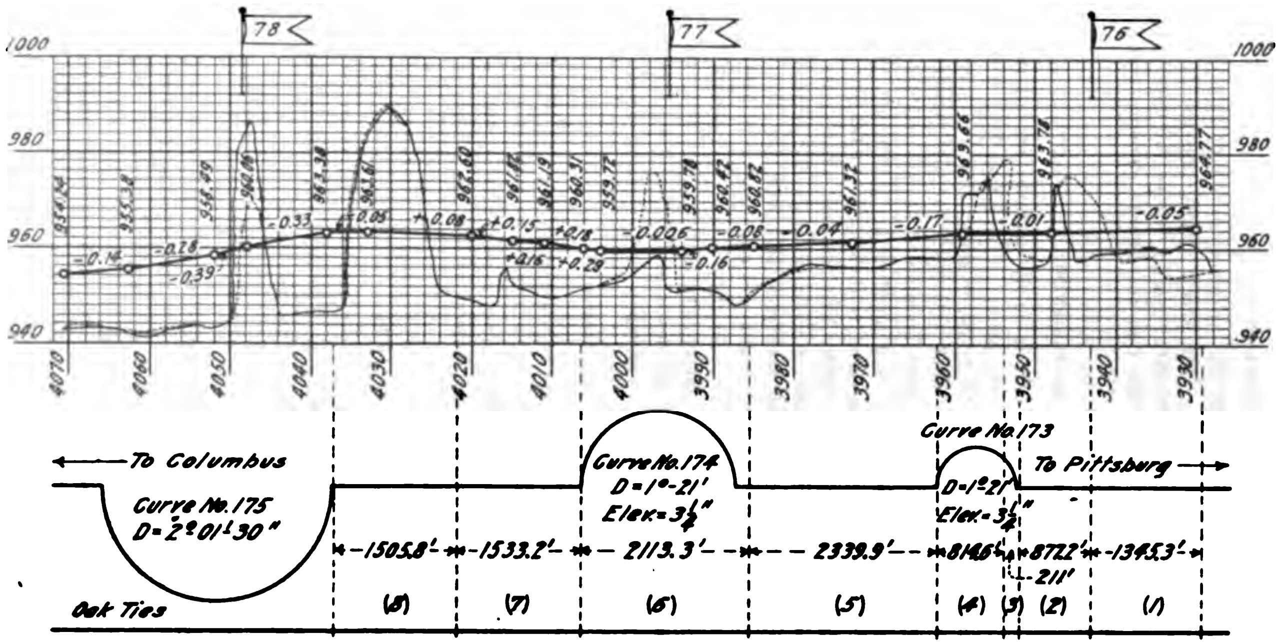


DIAGRAM SHOWING EXPERIMENTAL TRACK AT SCIO, OHIO.

Group 1— 784 shortleaf pine ties, screw spikes, linings and tie plates.
Group 2— 487 shortleaf pine ties, common spikes and tie plates.
Group 3— 115 red oak ties, common spikes and tie plates.
Group 4— 485 red oak ties, screw spikes, linings and tie plates.
Group 5—1273 shortleaf pine ties, screw spikes, linings and tie plates.
Group 6—1147 red oak ties, screw spikes, linings and tie plates.
Group 7— 826 red oak ties, screw spikes and linings.
Group 8— 808 red oak ties and common spikes.

STATEMENT SHOWING COST OF MAINTENANCE PER FOOT OF TRACK ON EXPERIMENTAL TRACK, SCIO, OHIO.

February, 1910, to January 31, 1913.

Table I

Type of Track	Surfacing	Lining	Gaging	Tightening Rail Fastenings	Renewing Rail Fastenings	Tightening Joint Bolts	Renewing Joint Bolts	Total Labor	Cost of Material Used in Renewal	Grand Total
Treated Red Oak Ties—Screw Spikes, Linings and Tie Plates (No. 4 and No. 6)....	$.3332	$.0372	$.0093	$.0231	$.1240	$.0006	$.0036	$.5309	$.2887	$.8196
Treated Red Oak Tids—Screw Spikes and Linings (No. 7)....................	.1651	.0413	......	.0365	.0964	......	.0011	.3405	.3419	.6824
Treated Pine Ties—Screw Spikes, Linings and Tie Plates (No 1 and No. 5)....	.1502	.0483	.0069	.0222	.0880	.0014	.0020	.3190	.3376	.6566
Treated Red Oak Ties—Common Spikes (No. 8)......	.1730	.0081	.0028	.0299	.0023	.0034	......	.2195	.0035	.2230
Treated Red Oak Ties—......Common Spikes and Tie Plates (No. 3).............	.1211	.0493	.0088	.1367	......	......	......	.3159	......	.3159
Treated Pine Ties—Common Spikes and Tie Plates (No. 2).............	.2045	.0021	.0026	.0277	......	......	......	.2369	......	.2369

Cost figures previous to February, 1910, are not separated between various kinds of fastenings.

PHYSICAL CONDITION AT FINAL INSPECTION.

The widest gage, with a few exceptions, found at the time of final inspection, was 4 ft. 9 in., a great deal of the track being 4 ft. 8¾ in. and 4 ft. 8⅞ in. The percentage of various gages for each group is shown in Table II. The widest gage occurring in group 6 was laid on the 1 deg. 31 min. curve at milepost 77. The wide gage of this rail was due in part to the canting of the rail, indicating that double spiking should have been provided on the inside of the rails.

The percentage of loose screws varies from 10 on group 7, to 41 on groups 4 and 6. Groups 4 and 6 being on curves, were no doubt subject to a greater canting than those in groups 1 and 5, located on tangent track, consequently there was a greater number of loose ones. The small percentage of loose screws on group 7 may be attributed to the fact that no tie plates were used. The rusting away of the tie plates evidently caused a great many of the screws to become loose, as this permitted greater wave motion in the rail under traffic, subjecting the screws to greater strain and causing them to work loose. An examination of the track without tie plates showed that the rail and tie were

held rigidly to each other under traffic, while on the tracks laid with tie plates only the rail moved up and down under traffic.

The condition of the intermediate screws and tie plates was very bad, many of the plates having rusted almost entirely away, presumably largely due to the action of the brine from refrigerator cars. The screws in some cases were almost destroyed, their threads having been taken away, permitting the screws to be lifted out of the ties. Many screws were worn under the head, and bent. The bending could be overcome by designing a tie plate that would support the head of the screw and assist in resisting the lateral thrust of the rail. The tie plates had all cut into the ties about a quarter of an inch, as had the rail on the ties without plates. Some ties were crushing under the plates. The joint screws, with the exception of being loose, and plates were in good condition. Some screws could be raised an inch, due, no doubt, to the tie decaying around the lining, permitting it to become loose.

The joint screws which were installed in 1910 with Lakhovsky linings, clips and larger tie plates were giving satisfactory service. They were not bent and all were in good condition with the exception of a few of the linings being loose, as noted above. At a great many of the joints, the rail, tie and tie plates seemed to be held firmly to each other, and the entire joint moved up and down under traffic. The joints were all in fairly good line and surface, and this type of fastening seemed to give much better service than the smaller intermediate screws.

The ties apparently were in good condition; a few were split and several broken and decayed, but the greater part were in as good condition as when installed. All the joint ties in group 8 were slewed. Many of these are laid through a cut where the drainage is not first-class, which may account for the slewing. Some of the ties in groups 4, 6, 7 and 8 were split, some of them through the spike holes. The pine ties do not show any signs of splitting. An oak and a pine tie were removed from the track and they did not show any indication of decay on the bottom. The spike holes did not show any signs of spreading.

The general condition of the track was good, the failing of the screws being principally due to the action of the brine on them and on the tie plates, and to the design being too light.

The various conditions of the ties and fastenings are shown on the accompanying photographs.

CONDITION OF EXPERIMENTAL TRACK WEST OF SCIO, OHIO

February 26, 1913

Table II—Table Showing Gage

Gage		4'-8½"	8⅝"	8¾"	8⅞"	9"	9⅛"	9¼"	9⅜"	9½"
Group 1	Per Cent	....	5	48	14	33	......	......	......	......
" 2	" "	....	31	23	31	15	......	......	......	......
" 3	" "	....	....	....	75	25	......	......	......	......
" 4	" "	....	....	43	14	43	......	......	......	......
" 5	" "	....	3	30	15	46	3	3	......	......
" 6	" "	....	....	6	17	55	....	11	6	6
" 7	" "	....	....	....	5	68	18	9	......	......
" 8	" "	5	9	30	35	21	......	......	......	......

Table III—Percentage of Loose Spikes

Groups	Per Cent
No. 4 and No. 6	41
No. 7	10
No. 1 and No. 5	18

RECORD OF PHYSICAL CONDITION OF EXPERIMENTAL TRACK AT SCIO, OHIO.

February 26, 1913.

Type of Track	Line	Surface	Gage	Loose Spikes	Worn Spikes	Bent Spikes	Broken Inter Spikes	Broken Joint Spikes	Loose Clips	Broken Clips	Slewed Ties	Tie Cut by Rail	Tie Cut by Plates	Condition of Ties
Treated Red Oak Ties—Screw Spikes, Linings and Tie Plates......	G	G	4'8½" 4'9½"	1420	......	....	*889	14	433	0	0	....	All ties ½"	23 split 1 failing
Treated Red Oak Ties—Screw Spikes and Linings..............	G	G	4'8⅝" 4'9⅛"	168	......	....	5	2	153	4	0	All ties ½"	....	18 split
Treated Pine Ties—Screw Spikes, Linings and Tie Plates......	G	G	4'8½" 4'9"	868	......	....	*348	24	557	0	0	....	All ties ½"	G
Treated Red Oak Ties—Common Spikes	G	G	4'8½" 4'9"	....	All Joint	....	....	....	....	....	All Joint Ties	All ties ½"	....	30 split 3 broken
Treated Red Oak Ties—Common Spikes and Tie Plates..........	G	G	4'8⅞" 4'9"	....	All Joint	....	....	....	....	....	......	....	All ties ½"	8 split
Treated Pine Ties—Common Spikes and Tie Plates..........	G	G	4'8½" 4'9"	....	All Joint	....	....	....	....	....	......	....	All ties ½"	G

Marks—(Line, Surface and Ties)—"E" Excellent; "G" Good; "P" Poor; "B" Bad: "M" Medium.
Gage—To be measured and recorded.
"Loose," "Worn" and "Bent" Spikes, etc., to be reported by number.
Remarks—*952 due to wreck of No. 30, February 20, 1910, of which 938 have been replaced with common spikes.

TREATED RED OAK TIES.

JOINT TIES.

SCREW SPIKES, LAKHOVSKY LININGS AND TIE PLATES.

No. 8.—Taken from the middle of Curve 174—full elevation of 3¼ in. Gage 4 ft. 9 in. Tie mashed ¾ in. under plate, and split at extreme end, but not through spike hole.

No. 14.—Taken from the west end of Curve 173—full elevation of 3¼ in. Gage 4 ft. 8¾ in. Half the lining was missing and the top of the other half broken off. Tie had a slight heart crack.

No. 6.—Taken from west spiral of Curve 174—elevation 2 in. Gage 4 ft. 8¾ in. Center of tie entirely decayed, so that the spike had no hold. Cut ¼ in. by plate.

No. 10.—Taken from east end of Curve 174—full elevation of 3¼ in. Gage 4 ft. 9 in. Heart wood loose as though in early stage of decay. A slight discoloration around the spike hole, due to the iron in the spike, is plainly visible.

No. 9.—Taken from east end of Curve 174—full elevation of 3¼ in. Gage 4 ft. 9 in. Tie split and cut about ¼ in. by plate; also slightly discolored around spike hole.

TREATED RED OAK TIES. JOINT TIES. SPIKES IN POSITION.

TREATED RED OAK TIES. JOINT TIES. SPIKES REMOVED.

TREATED PINE TIES.

JOINT TIES.

SCREW SPIKES, LAKHOVSKY LININGS AND TIE PLATES.

No. 21.—Taken from tangent east of Curve 173—Gage 4 ft. 9 in. Tie badly split on end; heartwood loose. Cut ¼ in. by tie plate.

No. 20.—Taken from tangent east of Curve 173—Gage 4 ft. 9 in. Tie slightly smashed and cut by tie plate.

No. 13.—Taken from tangent west of Curve 173—Gage 4 ft. 8¾ in. Tie badly mashed by tie plate and decayed through spike hole; however, tie retained the treating.

TREATED PINE TIES. JOINT TIES. SPIKES IN POSITION.

TREATED PINE TIES. JOINT TIES. SPIKES REMOVED.

TREATED RED OAK TIES.

INTERMEDIATE TIES.

No. 1.—Red oak tie with common spikes; taken from tangent east of Curve 175—Gage 4 ft. 8¾ in. This was a joint tie; split from end to end and badly decayed around spike hole, allowing little or no hold for the spike.

No. 2.—Red oak tie with screw spikes and Thiollier helical linings; taken from tangent west of Curve 174—Gage 4 ft. 9 in. Tie badly split through spike hole; partly exposed lining and spike, thus allowing very little hold for it.

No. 3.—Red oak tie with screw spikes and helical linings; taken from tangent west of Curve 174—Gage 4 ft. 9¼ in. Tie badly split at end, but not through spike hole, except for a slight horizontal crack, around which the wood is loose.

No. 7.—Red oak tie with screw spikes, helical linings and Glendon tie plates; taken from west end of Curve 174—Gage 4 ft. 8¾ in. Spike bent, but tie showed no marks of mashing or decaying.

TREATED RED OAK TIES. INTERMEDIATE TIES. SPIKES IN POSITION.

TREATED RED OAK TIES. INTERMEDIATE TIES. SPIKES REMOVED.

TREATED PINE TIES.

INTERMEDIATE TIES.

No. 16.—Treated pine ties with screw spikes, Thiollier helical linings and Glendon tie plates. Taken from tangent east of Curve 173—Gage 4 ft. 8⅞ in. Tie mashed under and off plate, and split at ends.

No. 17.—Treated pine ties with screw spikes, helical linings and Glendon tie plates. Taken from tangent east of Curve 173—Gage 4 ft. 9 in. Tie cut ¼ in. by plate and split at ends.

No. 11.—Treated pine ties with screw spikes, helical linings and Glendon tie plates. Taken from tangent east of Curve 174—Gage 4 ft. 8⅞ in. Tie cracked throughout, as shown, and cut ¼ in. by tie plate.

No. 19.—Treated pine tie with screw spikes, helical linings and Glendon tie plates. Taken from tangent east of Curve 173—Gage 4 ft. 8¾ in. Tie cut ¼ in. by tie plate—otherwise in good condition.

No. 12.—Treated pine tie with screw spikes, helical linings and Glendon tie plates. Taken from tangent east of Curve 173—Gage 4 ft. 8¾ in. Tie cut ¼ in. by plate and split at ends.

TREATED PINE TIES. INTERMEDIATE TIES. SPIKES IN POSITION.

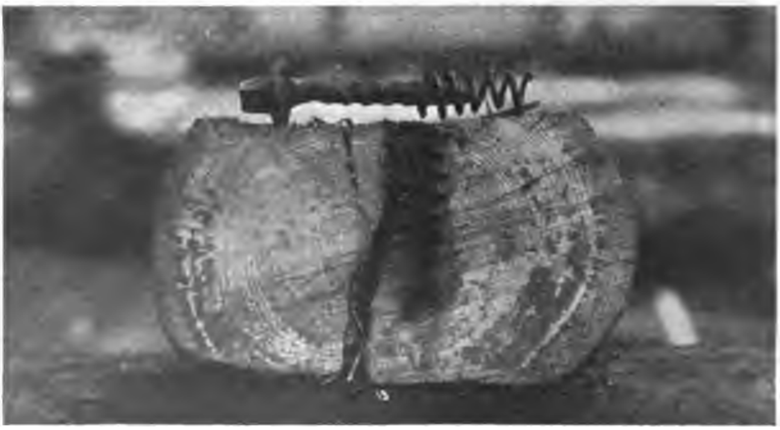
TREATED PINE TIES. INTERMEDIATE TIES. SPIKES REMOVED.

TREATED RED OAK TIE.

INTERMEDIATE TIES.

No. 15.—Red oak tie with screw spikes, Thiollier helical linings and Glendon tie plates. Taken from middle of Curve 173—full elevation of 3¼ in. Gage 4 ft. 8¾ in. Tie split through spike hole and cut by tie plate. Spike in bad condition; bent and worn under cap. Tie shows distinctly the iron discoloration around the spike.

TREATED RED OAK TIE. INTERMEDIATE TIE. SPIKE IN POSITION.

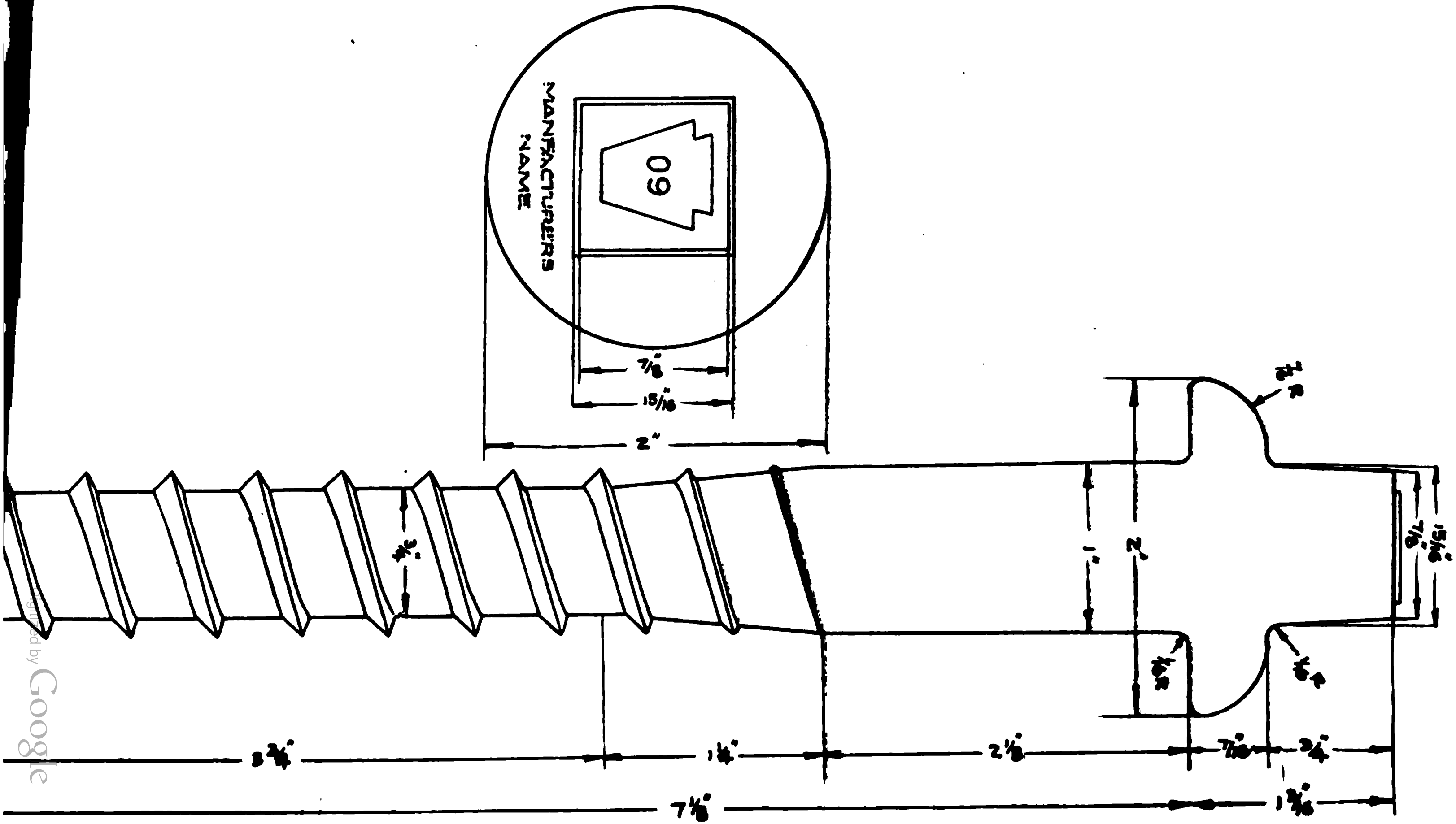


TREATED RED OAK TIE. INTERMEDIATE TIE. SPIKE REMOVED.

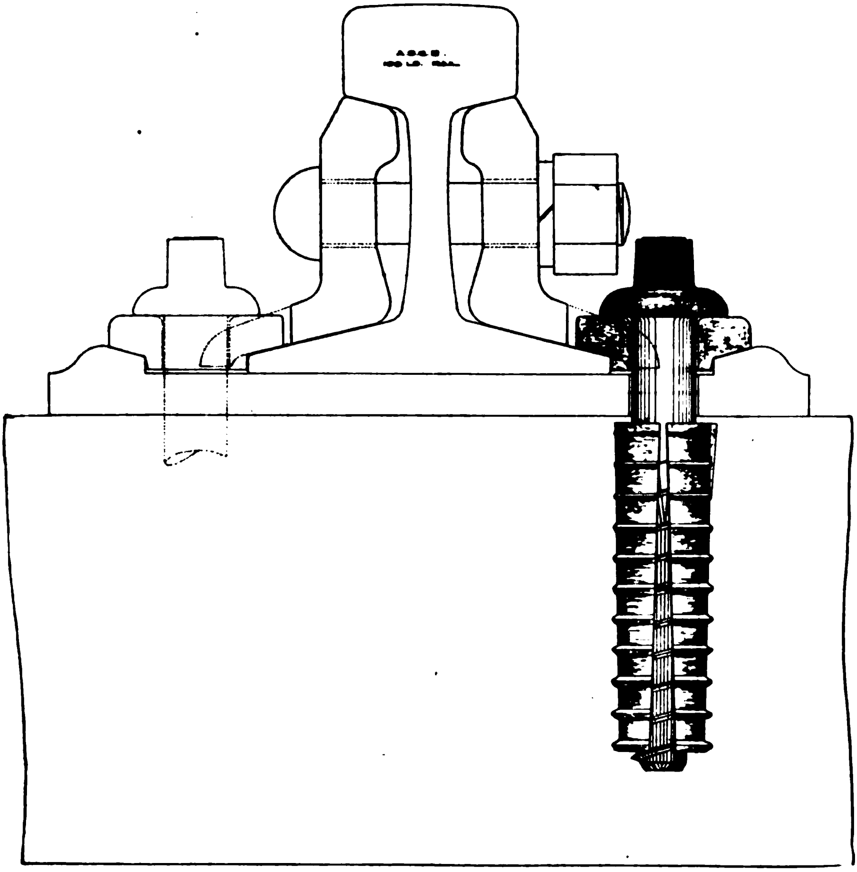
RENEWAL OF JOINT SCREWS WITH LAKHOVSKY LININGS, HEAVIER PLATES, CLIPS AND SCREWS.

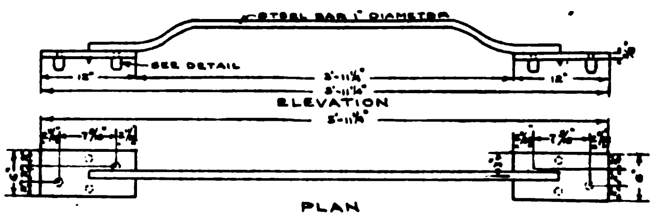
In 1910 it was necessary to renew all joint spikes on account of the action of the rail creeping and shearing the heads of the spikes. New angle bars, heavier tie plates and screws, provided with clips and Lakhovsky linings were used in the work. The ties were removed from the track, new holes were bored by hand, and the linings applied. Print of plan dated March 5, 1909, revised April 3, 1909, show the details of this fastening, plates, etc. The above work greatly increased the cost of maintenance for the screw spikes.

Screw spikes may be a satisfactory form of fastening for use on bridge floors, or in tunnels, terminal stations, etc., provided the problem of repairs is satisfactorily solved. Attached plans and photographs show types of fastenings in use on bridge floors on this division and which are giving satisfaction up to the present time. These types are fastenings we hope will increase the life of the bridge ties, and can be used satisfactorily with pine ties on bridges.

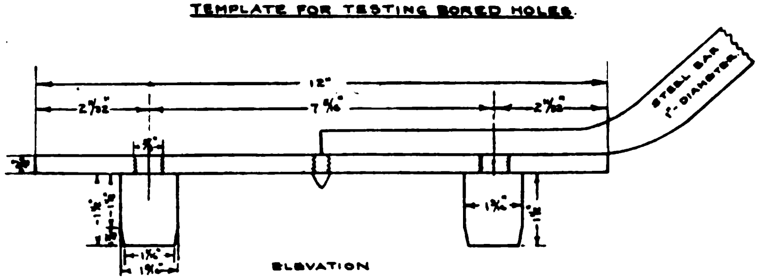


Details for Test of Screw Spike, Clip, Tie Plate and Lakhovsky Lining.



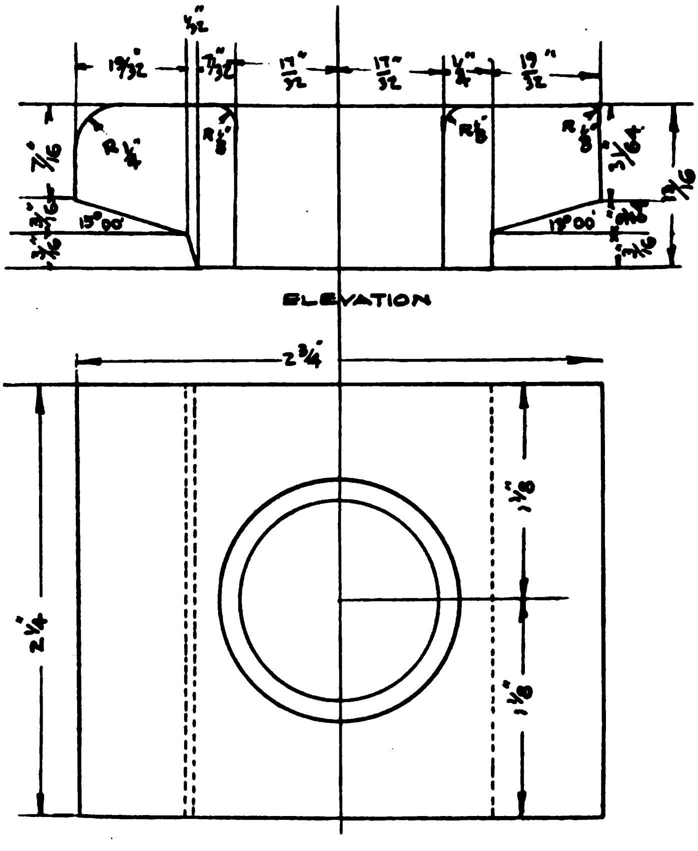


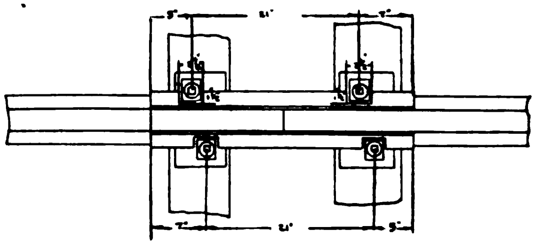
TEMPLATE FOR TESTING BORED HOLES.



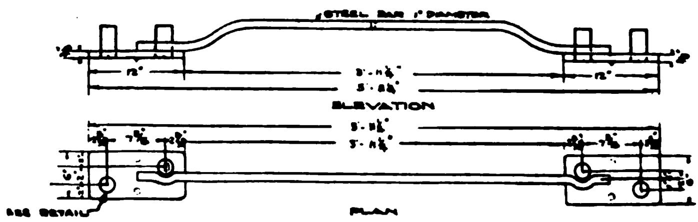
DETAIL OF TEMPLATE FOR TESTING BORED HOLES.

DETAILS FOR TEST OF SCREW SPIKE, CLIP, TIE PLATE AND LAKHOVSKY LINING.



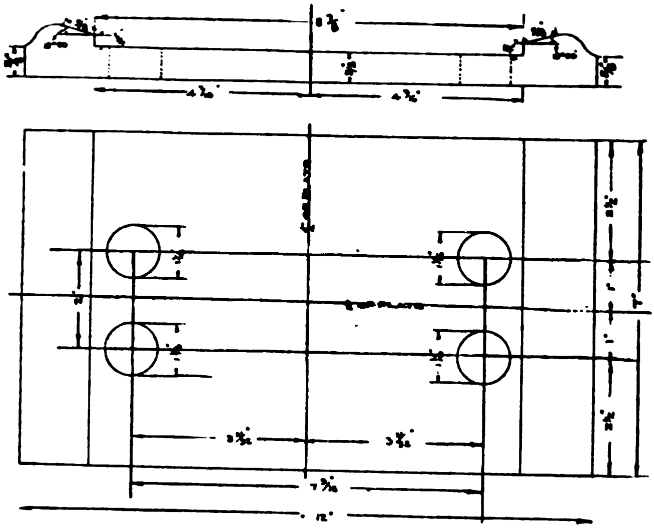


DETAIL FOR SLOTTING ANGLE BARS

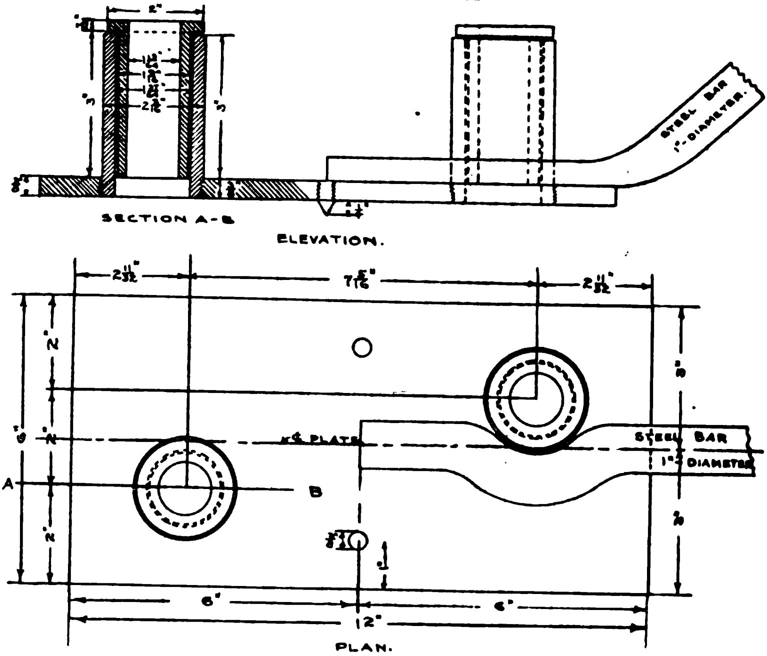


TEMPLATE FOR BORING HOLES

DETAILS FOR TEST OF SCREW SPIKE, CLIP, TIE PLATE AND LAKHOVSKY LINING.

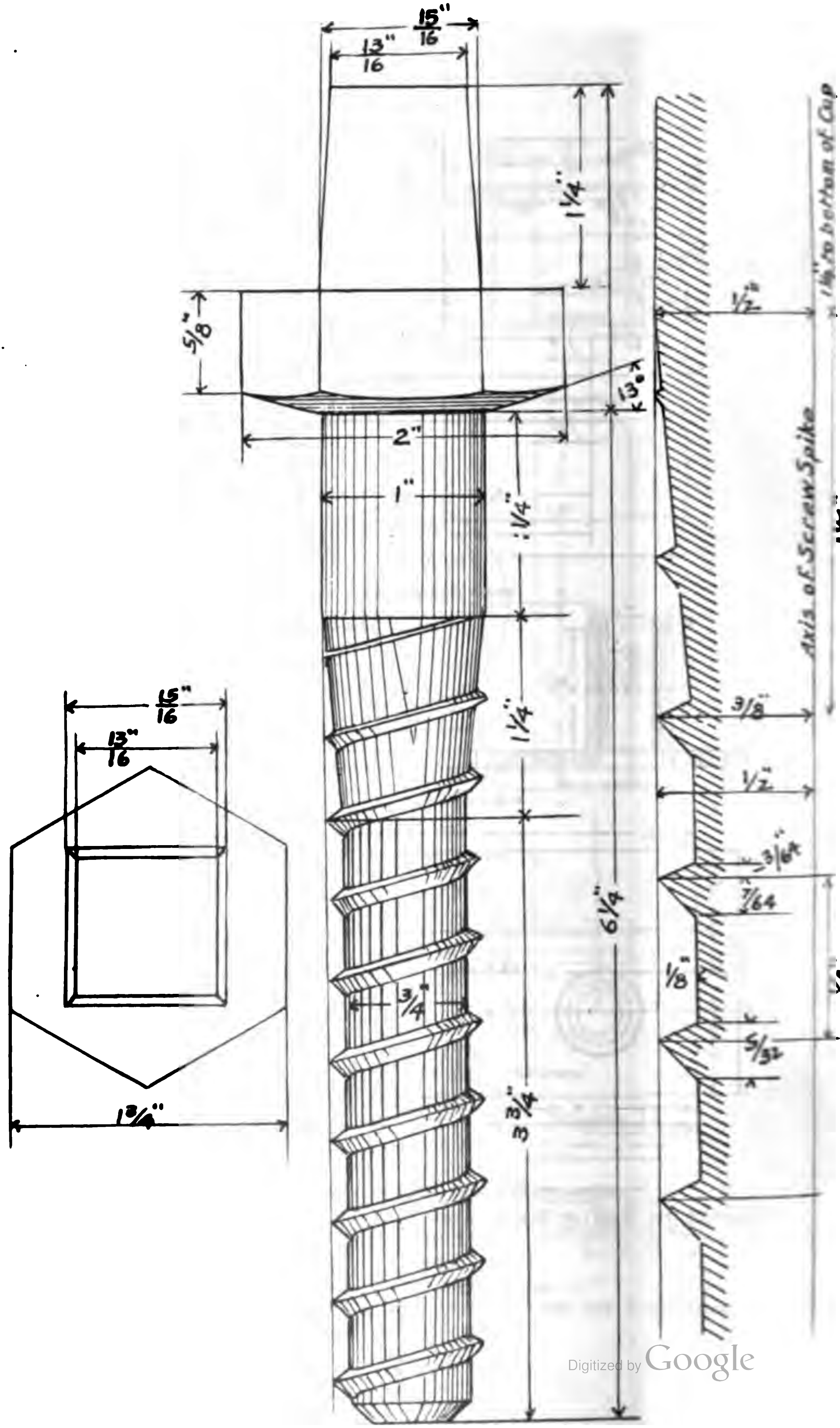


DETAIL OF TIE PLATE

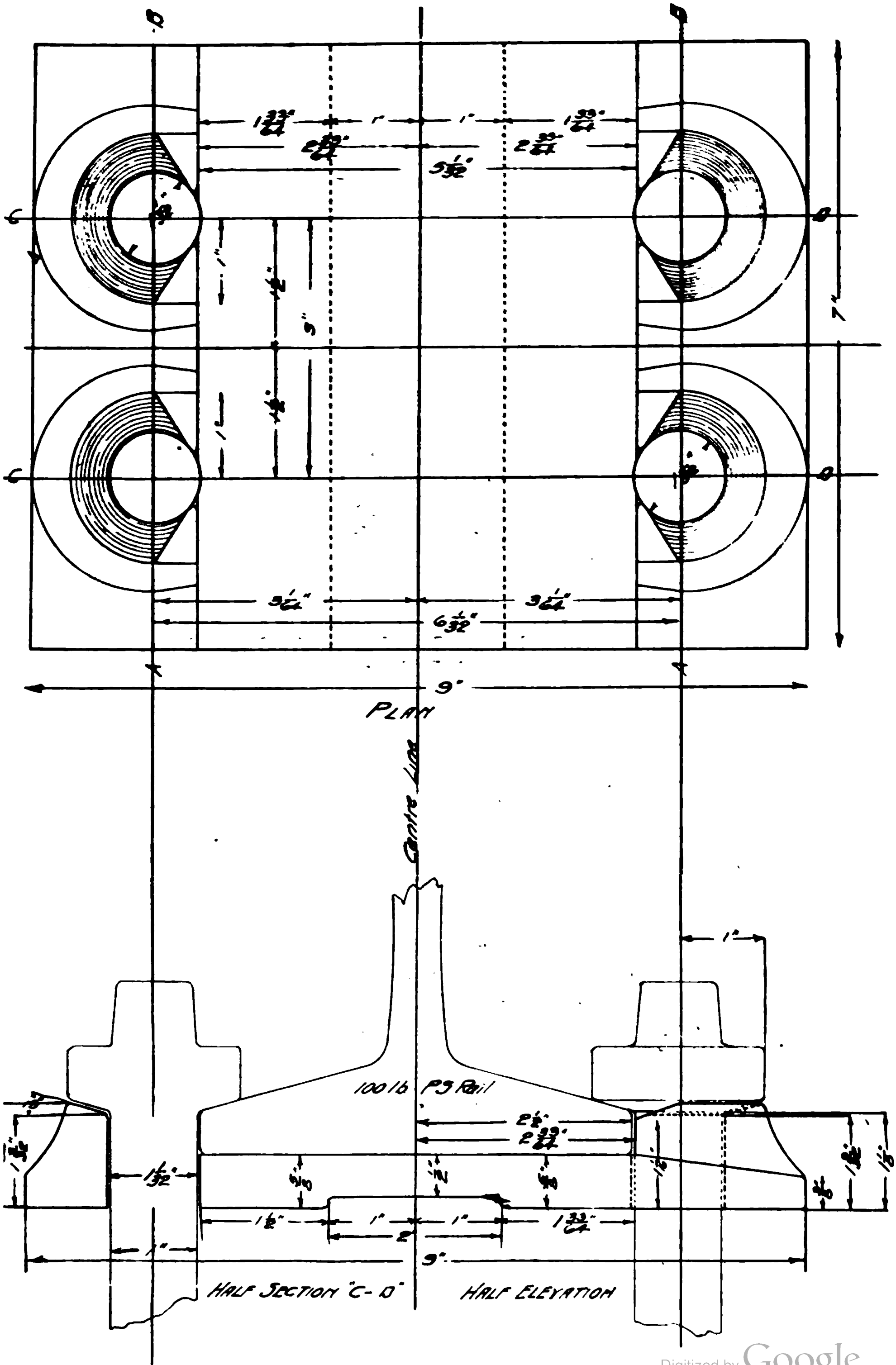


DETAIL OF TEMPLATE FOR BORING HOLES.

DETAILS FOR TEST OF SCREW SPIKE, CLIP, TIE PLATE AND LAKHOVSKY LINING.



15/16"
13/16"
1 1/4"
5/8"
13°
2"
1"
1 1/4"
1 1/4"
6 1/4"
3/4"
3 3/4"
1/2"
3/8"
1/2"
3/64"
7/64"
1/8"
5/32"
Axis of Screw Spike
1 1/16" to bottom of Cup
15/16"
13/16"
1 3/4"



MALLEABLE IRON TIE PLATE FOR USE WITH SCREW SPIKES.

Ohio Connecting Bridge No. 3. East Leg of Y. Screw Spikes and Rolled Steel Tie Plates, P. R. R. Standard. Applied May, 1911.

Screw Spikes and Rolled Steel Tie Plates, P. R. R. Standard. Applied May, 1911, North Rail.

Screw Spikes and Rolled Steel Tie Plates, P. R. R. Standard. Applied May, 1911, North Rail.

Screw Spikes and Malleable Iron Tie Plates Applied June, 1910. West End Bridge No. 42, Westbound Track, Outside South Rail.

Screw Spikes and Malleable Iron Tie Plates Applied June, 1910.
View on Bridge No. 42, West End Westbound Track.

Screw Spikes and Malleable Iron Tie Plates Applied June, 1910.
West End Bridge No 42, Westbound Track, South Rail.

Appendix A.

DESCRIPTION OF EXPERIMENT WITH TREATED CROSS-TIES, WOOD SCREWS AND THIOLLIER HELICAL LININGS.

MAY 23, 1908.

BY W. D. WIGGINS, Division Engineer, Pittsburgh Division.

Before entering into a description of the experiment referred to in the above heading, it will not be amiss to summarize the conditions surrounding the cross-tie problem in this country at the present time.

It is well recognized that the supply of white oak timber in this country is being rapidly depleted and that the railroads will be obliged within the next few years to resort to the use of steel, concrete or the cheaper woods treated by one of the preservative processes, as a substitute for the untreated white oak cross-tie of to-day. The economy and practicability of the use of steel or concrete for cross-ties in this country has not yet been satisfactorily demonstrated. On the other hand, it cannot be questioned that the use of the cheaper woods, when treated by one of the approved preservative processes and properly protected from rail-wear and spiking, is economical, as compared with white oak at the present market price.

The average life of white oak cross-ties on these lines is from 7 to 9 years. On divisions where the curvature is light, and life of rail considerable, the ties are, for the most part, removed from the track on account of decay, but in territory where there is a large percentage of sharp curvature and heavy traffic, resulting in frequent rail renewals and gage connections, the ties will become spike-killed within the period of their natural life. Such conditions require the use of a more effective rail fastening than the nail spike—one providing proper holding power; permitting of the renewal of the rail without damage to the tie, such as results when nail spikes are several times pulled out and driven in at other points; also providing for small changes of gage, either to correct bad line or to correct the gage widened by curve-wear. Softwood ties will be largely used in the future on account of low cost, available supply, ease with which softwood lends itself to chemical treatment, and satisfactory life obtained when treated and protected against abrasion and damaging effect of the present form of rail fastenings. Tie plates will be required on such ties, whether located on a curve or tangent. The objections to the nail spikes as a rail fastening apply to a greater extent in the case of softwood than with hardwood, for the following reasons:

First.—The holding power of the spike and resistance to loosening are less in soft than in hardwood.

Second.—Damage to the wood fiber by the spike is more pronounced.

Third.—Increased number of re-spikings necessary, due to "First."

Unless the rail fastening problem is given proper consideration by the users of chemically-treated timber for cross-ties, such use will prove a disappointment and source of financial loss.

For the above reasons, the General Manager, on November 10, 1905, authorized the Chief Engineer Maintenance of Way, to make an experiment with wood screws and Thiollier's helical linings on two miles of track on the Pittsburgh Division, with a view of ascertaining if they are a proper form of rail fastening for use with treated ties.

After carefully looking over the division, it was decided to make the test of these fastenings in the eastbound main track between mileposts 76 to 78, west of Scio, Ohio. The alinement is about one-half curve and one-half tangent, the rail new 100-lb. A. S. C. E. section, and the track newly ballasted with stone.

In order to insure that the life of the ties with which the test was made would be equal to that of the rail fastenings, it was decided to treat them with creosote, but, inasmuch as the test was to be one of rail fastenings rather than of creosoted timber, it was thought that an injection of 2½ gallons of creosote per tie would be sufficient, as this would insure a life of 15 years—a period sufficiently long to demonstrate the value of the rail fastening. It was decided to use an equal number of red oak and loblolly pine ties. Kentucky shortleaf pine was afterwards substituted for the loblolly pine, owing to the difficulty in obtaining the latter wood. Tie plates were to be used on all of the pine ties and none of the pine ties to be placed on curves. In order to compare the fastenings, the red oak ties were laid in the following manner:

On curves—Part with screw spikes, helical linings and tie plates.

On tangent—Part with screw spikes and helical linings, but without tie plates. Part with common nail spikes and without tie plates. Part with common nail spikes with tie plates.

The pine ties were laid, part with screw spikes, helical linings and tie plates; part with common nail spikes and tie plates. Diagram 507-123A, showing the location and distribution of cross-ties and rail fastenings, is attached hereto.

DESCRIPTION OF MATERIAL AND APPARATUS AND METHODS USED IN THE TEST.

CROSS-TIES.

The number and kind of ties used, preservative treatment, etc., are shown in the following table:

Kind of Wood.	No. of Ties.	Preservative Treatment.
Red Oak 7 in. by 8 in.	3,789	2½ gallons creosote per tie
Shortleaf Pine 7 in. by 8 in.	2,494	2½ gallons creosote per tie
	6,283	

The ties were purchased in the South and after being air-seasoned for from six to fifteen months were treated by the Columbia Creosoting Company at Shirley, Ind. In their process, the ties are first thoroughly air-seasoned and then placed in a retort and immersed in hot creosote oil under a pressure of 175 lbs, per sq. in. from 1 to 1¾ hours, depending

on the kind of wood. About four gallons of the oil are injected into each tie by this process. The retorts are then drained, and a vacuum maintained for from 1¼ to 1¾ hours, resulting in the withdrawal of about 1½ gallons of oil from each tie. The ties, after their treatment, were inspected by a representative of the C. C. C. & St. L. Ry. Co. who is regularly stationed at this point, and were then air-seasoned from two to five months before being placed in the track. After treatment, the red oak ties were found to have been penetrated to a depth of from 2 to 2½ inches, while the pine ties were almost entirely permeated with the oil. The report of treatment showed an actual net absorption of from 2.82 to 5.20 gallons per tie for the pine, and from 2.48 to 3.71 per tie for red oak. A number of the ties were found not good enough for the test. They were treated however, and used in the track with ordinary fastenings.

DATING NAILS.

Dating nails were placed in the ties as follows:

Creosoted red oak..............	CR	RO	07
Creosoted shortleaf pine........	CR	SL	07

The dating nails were furnished by the American Steel & Wire Company and the C. C. & E. P. Townsend Co., and are made of galvanized iron. They are ¼-in. in diameter, 2¼ in. in length, with head ⅝-in. in diameter, having stamped thereon letters and figures designating the year, treatment and kind of wood.

SCREW SPIKES.

The screw spike in use on the French-Eastern Railway was used in the test. It is 5½ in. long under the head, ½-in. in diameter at the root of the thread, with a thread 5/32-in. in depth. The diameter at the root of the thread is increased from ½-in. to 13/16-in. at the shank to insure tightening of the spike in the last turn when applied. The pitch of the thread is two turns to the inch. The under face of the head is formed at right angles to the axis of the screw, or nearly so. The head is made with a ¾-in. square top, tapering to ⅝-in. at the upper end. This screw might be improved by forming the under face of the head at an angle of 13 deg., with the axis of the screw, as shown on blueprint 7451, so as to fit the upper face of the base of A. S. C. E. rail. The square top for engaging the socket wrench, used in seating the screw, should be made without the taper, as the wrench was found to lift on this taper when the screw was being seated in the tie. Eighteen thousand of these screw spikes were purchased from Jean Thiollier, of Paris, France.

THIOLLIER'S HELICAL LININGS.

The Thiollier helical lining is a coiled steel lining for the threaded hole in the tie in which the screw spike is inserted. In the words of the inventor, its aim is as follows:

(1) To provide for the screw spike a strong and evenly bored recess, so that it can be removed and replaced without damaging its box.

(2) To allow a greater hold on the wood fibers, and, therefore, to increase the resisting power of the wood.

(3) To have in direct contact with the wood fibers, surfaces without asperites, which will never deteriorate them under any influences.

These results are arrived at by means of a helical lining of steel, resembling in shape a spiral spring, and having the same pitch as the screw spike. This spring is interposed perpendicularly to the core of the screw spike, between the latter and the wood.

Eighteen thousand of these linings were purchased from Jean Thiollier.

TIE PLATES.

The tie plates used were of the flat-bottom type, 6x9 in., and 15/32 in. thick. They were punched with round holes to fit the screw spike and were furnished by the Dilworth-Porter Company of Pittsburgh.

ANGLE BARS.

Special angle bars of the Standard section, punched with round holes to receive the screw spikes, were used.

TOOLS AND METHODS USED IN BORING THE TIES AND APPLYING HELICAL LININGS.

This work was done at the creosoting works before the ties were treated. The work was executed by six carpenters in the employ of the railway company. The procedure was as follows:

On hewed ties, the rail seats were adzed, so as to bring them in the same plane. This work was done by hand, a template being used to insure the accuracy of the work. Holes of the proper diameter and spacing were then bored through the tie with ordinary auger and proper spacing template. The boring may be done by hand or power. In this case, a portable air-compressing plant, originally made for use in connection with the driving of rivets in bridge work, was used with a wood-boring air motor.

It is necessary to bore the holes entirely through the ties, as the thread-cutting tool could not otherwise be used, due to the accumulation of shavings from it in the bottom of the hole. Something over 17,000 holes were bored by this machine in a short time. A long time would have been consumed in boring these holes by hand.

The holes were properly spaced by using a steel template, bored to the proper spacing. The holes in the template were bushed with short studs, the inside diameter of which was slightly greater than the diameter of the bit used in the boring machine. The underface of the template was provided with sharp studs, about ¼ in. in length. Diagram 500/100, showing adzing and boring templates, attached thereto. It was the intention to affix this template to the ties by driving the studs into the wood; the operator would then stand on the template and bore the holes. The studs were to act as a guide in maintaining the bit in a

vertical position. In practice, it was found that these studs damaged the bits to such an extent that it was found necessary to change the method of boring the holes. The template was placed in position on the tie, and the exact location of the holes marked with a punch. The template was then removed and the holes bored, the operator relying on his eye to maintain the bit in a vertical position. It was found difficult to bore the holes to the exact gage and in an exactly vertical position by this method. Quite a number of them varied by as much as ⅛ in. in each direction from the correct position. The holes were then tapped with a special thread-cutting tool, furnished by Thiollier. The diameter of the tool at the root of the thread is the same as the diameter of the hole. This operation may be performed by hand, or with a boring machine. In this experiment, a compressed-air plant and a heavy air-motor, such as is used for machine work, were used. The air-motor was quite heavy, and in order to relieve the men and facilitate the work, it was mounted on a four-wheeled carriage, traveling on a narrow-gage track. In this machine, a horizontal lever, mounted near its middle on a vertical spindle, free to turn in any direction. The air-motor is supported at one end of this lever, which is provided with a counterweight at its other end. The arrangement is such that the motor can be readily handled by one man and swung by him into any desired position. This carriage was constructed of scrap material, at Dennison Shop, at small cost. Considerable power is necessary to drive the thread-cutting tool. The wood-boring motor was not of sufficient power for this work, and the heavy motor was used. The thread-cutting tool should be lubricated with soft soap to facilitate its progress into the wood. It was found advisable in case of hardwood to first use a tool of smaller size than the finished thread and then enlarge the thread with a second tool of larger diameter. If the thread be cut in one operation, the wood fibers will be considerably damaged and the thread cut with difficulty.

The helical lining is then seated in the hole by means of a driving mandrel, on which the lining is placed. A shoulder on the thread of the mandrel engages a special bend at the lower end of the lining, the lining is thus pulled into the tie. In practice, great difficulty was experienced in placing the linings by hand. When the lining was partly in place, the friction between it and the wood became so great as to straighten out the bend which engages the mandrel, permitting the latter to turn in the lining. In this event, it became necessary to remove the lining from the hole and replace the bend at its lower end, or replace the lining itself with a new one. The removal of the lining was accomplished with difficulty and many were broken during this operation, or in replacing the bend so that it might again be driven into the tie. Various attempts were made to overcome this difficulty. Both the diameter of the hole and the size of the thread were increased, within limits, without much success. A slight increase in the size of the hole, or of the thread-cutting tool, resulted in the lining being too loose and

coming out with the screw spike when there was occasion to remove it. A new design of driving tool, shown as No. 6 on attached photograph, was finally devised. This tool was provided with a shoulder, so as to engage the upper end of the lining, in addition to the one at the lower end. This tool pushed, as well as pulled, the lining into place. Some improvement was effected by the use of this tool, but the difficulty was not entirely overcome. In placing the lining by hand, the operation was accomplished by a succession of turns. The starting friction is, of course, considerably in excess of that existing while the lining is in motion. It was found that when the mandrel was driven by power, and the operation continuous from beginning to end, very little difficulty was experienced.

Although the adzing of the ties, boring of the holes, and insertion of the helical linings might be done successfully in the manner above described with a considerable number of ties, it would, without doubt, be necessary to use special machinery for executing work of this character on a large scale.

Photographs of the tools and machinery used in this experiment are attached hereto.

PLACING OF TIES IN TRACK, AND APPLICATION OF TRACK FASTENINGS.

The ties were put in the track and the fastenings applied during the months from June to November, 1907, inclusive, by an extra gang of about 25 men. Little or no difficulty was experienced. The screw spikes were run down three-fourths of their length with an alligator wrench and tightened by means of a socket wrench about 30 inches long, equipped with an ordinary brake-wheel at the upper end. Two men were required for operating each wrench.

Some time after the ties were put in, quite a number of variations in the gage was noticed, most of which seemed to be at the joints. The ties were inspected and some of the screws removed, and an examination made of the helical linings and the holes in the ties. No sign of spreading was discovered and the variations in gage, with the exception of a few cases, were not greater than one-eighth of an inch. The variations in gage were, without doubt, due to error in the spacing of the holes. A number of loose screws were found, but this resulted from settling of the tie plates into the ties. These were tightened and no subsequent loosening has been noticed.

COST OF EXPERIMENT.

Statement showing cost of labor and material entering into the test is given below. The cost per tie is quite high on account of the methods used for boring the ties and placing the linings. If this work were done on a large scale, with special machinery, the cost should be quite low—not to exceed one cent per tie.

STATEMENT OF COST OF CREOSOTED CROSS-TIES, FITTED WITH THIOLLIER'S HELICAL LININGS AND SCREW SPIKES.

		Labor	Material	Total
4084	Red Oak Ties @ $0.46		$1,878.64	$ 1,878.64
2548	Pine Ties @ $0.45		1,146.60	1,146.60
	Freight on Ties shipped to Shirley		1,000.23	1,000.23
	Freight on Ties returned from Shirley		224.00	224.00
	Freight on air compressor		34.00	34.00
	Freight on screw spikes from New York		33.68	33.68
1200	100-lb. Angle Bars, slotted for screw spike		744.00	744.00
7100	Glendon tie plates, punched for screw spikes		931.48	931.48
1188	Glendon tie plates, punched for common spikes		143.29	143.29
1215	Pounds Dating Nails		48.03	48.03
	Expenses of Carpenters	$ 291.65	....	291.65
6486	Ties, creosoted		1,945.20	1,945.20
57.567	Tons Coal for air compressor	....	100.74	100.74
	Unloading coal for compressor	8.40	....	8.40
	Pipe fittings, etc., for water line		4.05	4.05
	Truck for air motor for boring ties	41.80	7.40	48.58
4	Sets of Threading Tools @ $5.00		20.00	20.00
4	Augers @ $1.50		2.00	2.00
30	Pounds Airoiline Grease @ $0.20		6.00	6.00
1600	Intermediate screw spikes with helical linings @ $0.035		560.00	560.00
2200	Joint screw spikes with helical linings @ $0.04		80.00	80.00
7476	Common spikes @ $1.60 per C.		119.60	119.60
	Labor unloading tools for boring	190.00	....	190.00
	Labor adzing ties	321.65	....	321.65
	Labor boring ties	181.35	....	181.35
	Labor threading ties	177.40	....	177.40
	Labor inserting linings in ties	177.40	....	177.40
	Unloading creosoted cross ties	240.70	....	240.70
	Piling creosoted cross ties	40.20	....	40.20
	Distributing creosoted cross ties	324.15	....	324.15
	Surfacing and lining track	574.55	....	574.55
	Putting on tie plates	31.90	....	31.90
	Placing ties in track	1,764.90	....	1,764.90
		$4,365.43	$9,028.94	$13,394.37

	Labor	Material	Total
Cost per single tie, fitted with screw spikes and helical linings—			
Original cost per tie, including freight and dating nails	.....	.65	.65
Creosoting ties	.....	.30	.30
4 screw spikes with helical linings	.....	.1496	.1496
2 Glendon tie plates, punched for screw spikes	.....	.2624	.2624
Boring, threading and inserting linings	.27	......	.27
Adzing	.0496	......	.0496
Unloading and piling	.0447	......	.0447
Placing ties in track and surfacing	.429	......	.429
Total	.7935	1.3620	2.1553
Cost per signle tie, fitted with common spikes—			
Original cost per tie, including freight and dating nails	.....	.65	.65
Creosoting ties	.....	.30	.30
Glendon tie plates punched for common spikes	.....	.2412	.2412
Common spikes per tie	.....	.0640	.0640
Adzing	.0496	......	.0496
Unloading and piling	.0447	......	.0447
Placing ties in track and surfacing	.429	......	.429
Total	.5233	1.2552	1.7785

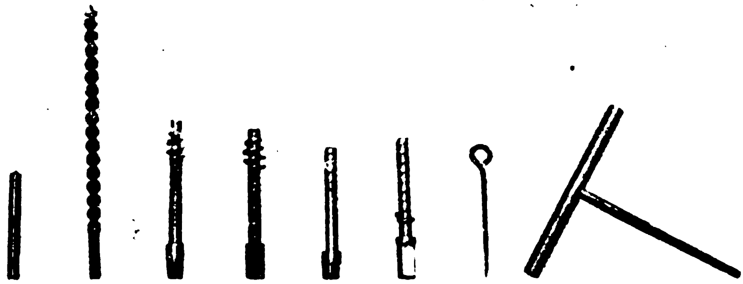
NOTE—Unit prices do not include angle bars or tools, except augers and threading tools worn out in boring ties. Item of cost of placing ties in track includes cost of distributing ties, placing same in track and applying tie plates

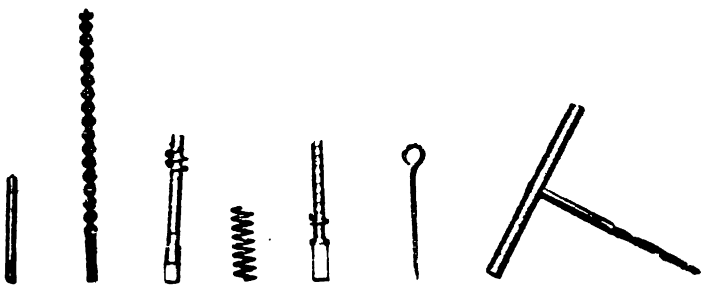
Template for Spacing of Holes to Be Bored in Ties.

Boring 1½-In. Hole in Cross-Tie Before Cutting Thread for Lining.

Cutting Thread for Helical Lining.

Screw Spike Experiment. Inserting the Helical Lining in Tie. This Completes the Operation.





CAR CARRYING AIR COMPRESSOR FOR OPERATING BORING MACHINE.

GENERAL VIEW SHOWING HANDLING OF CROSS-TIES.

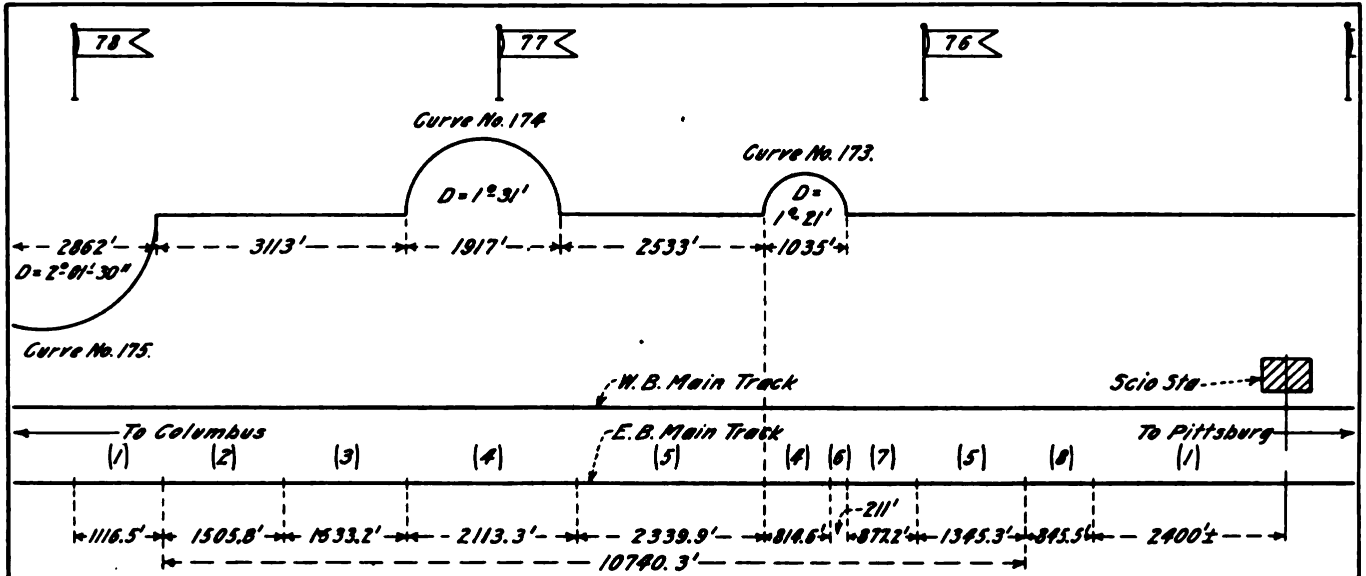
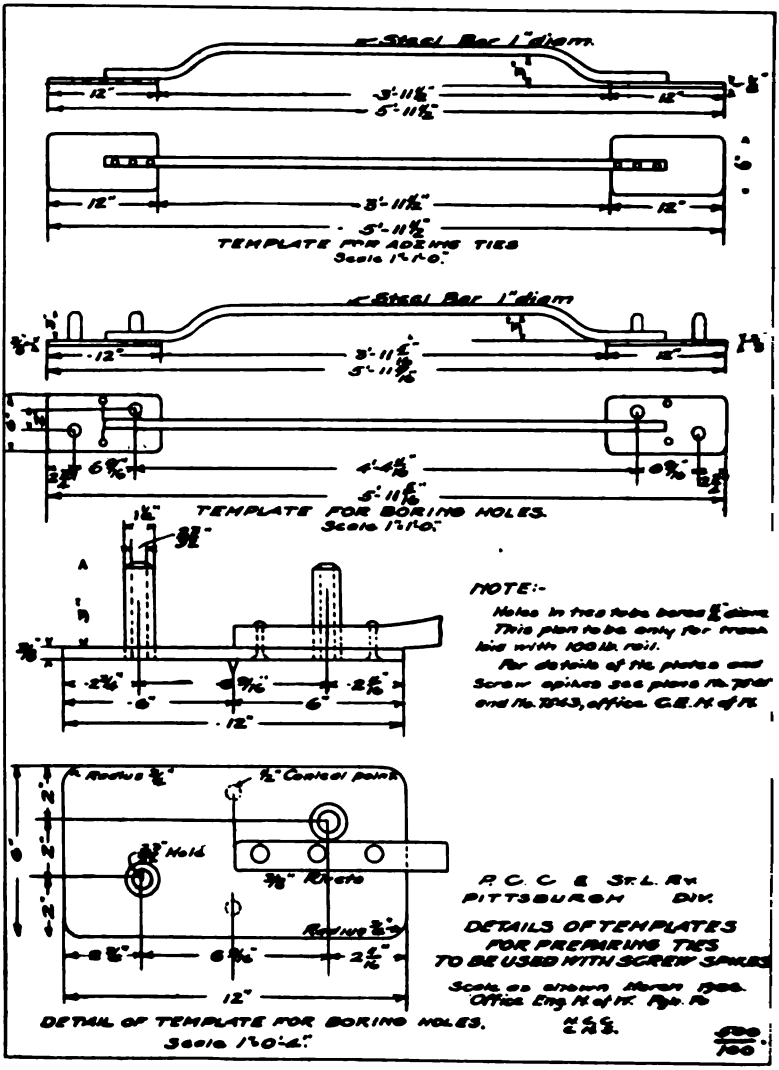
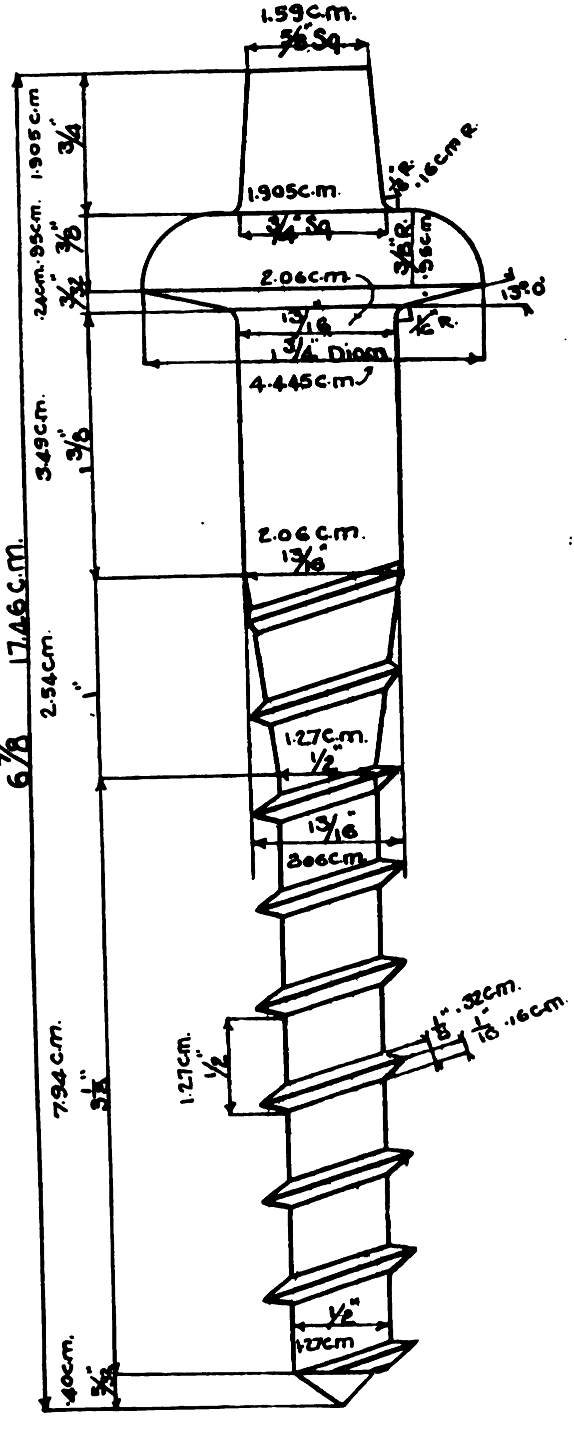


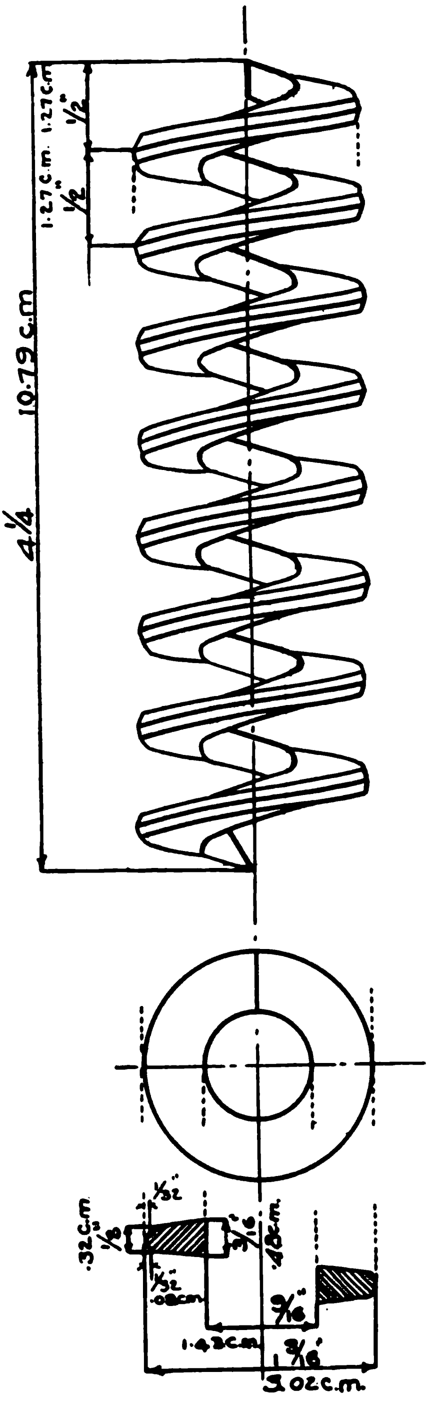
DIAGRAM SHOWING LOCATION AND PRESENT DISTRIBUTION OF CREOSOTED TIES.

Group.	No. and Kind.	Fastenings.	Location.
1.	Common oak ties.	Common spikes, with or without tie plates.	C. & T.
2.	808 treated red oak ties.	Common spikes.	Tangent.
3.	825 treated red oak ties.	Common spikes, helical linings.	Tangent.
4	1582 treated red oak ties.	Screw spikes, helical linings, tie plates.	Curve.
5.	2007 treated shortleaf pine.	Screw spikes, helical linings, tie plates.	Tangent.
6.	115 treated red oak ties.	Common spikes, tie plates.	Curve.
7.	487 treated shortleaf pine.	Common spikes, tie plates.	Tangent.
8.	*459 treated red oak ties.	Common spikes, tie plates.	Tangent.

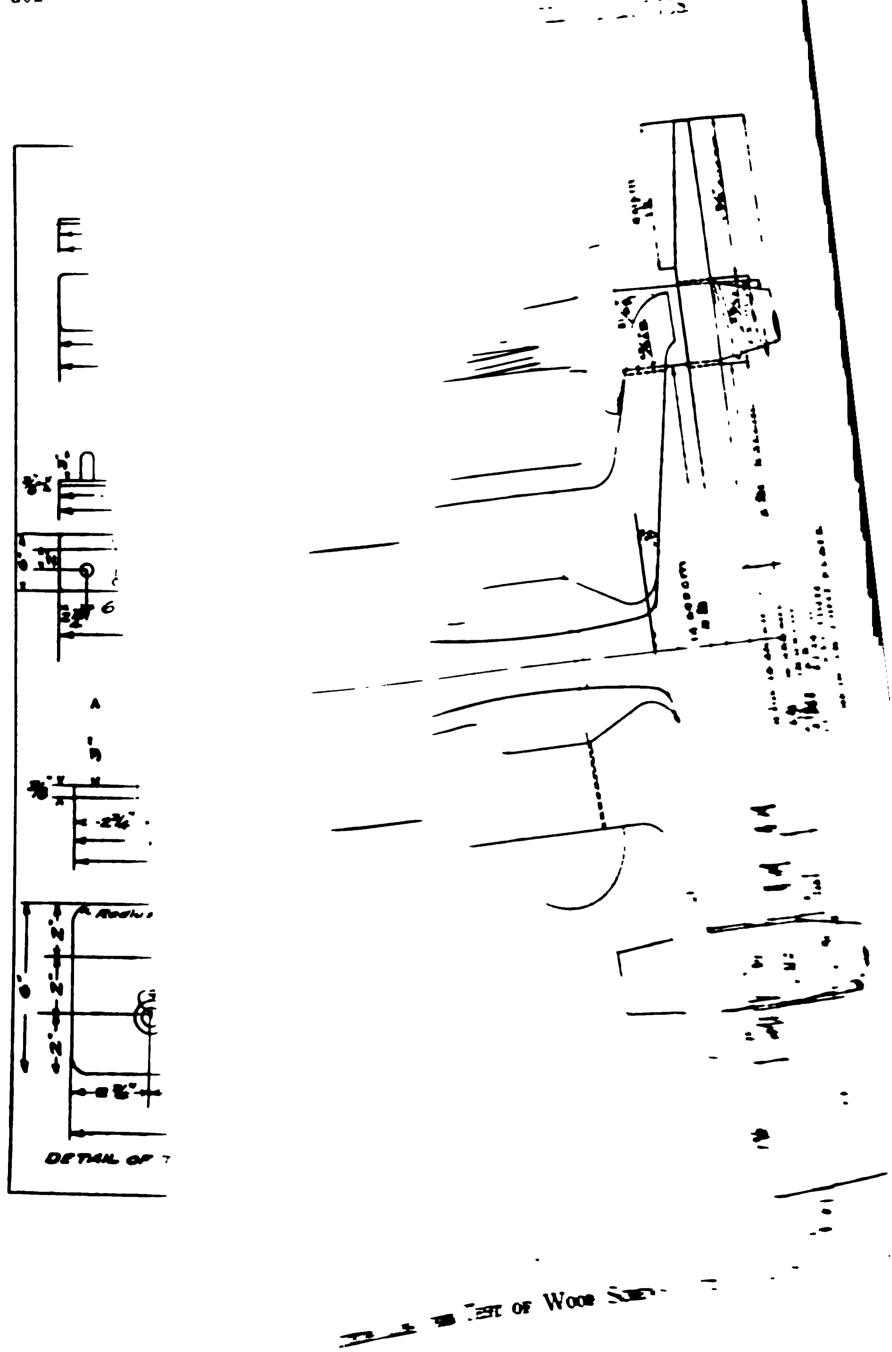
*Not included in test.

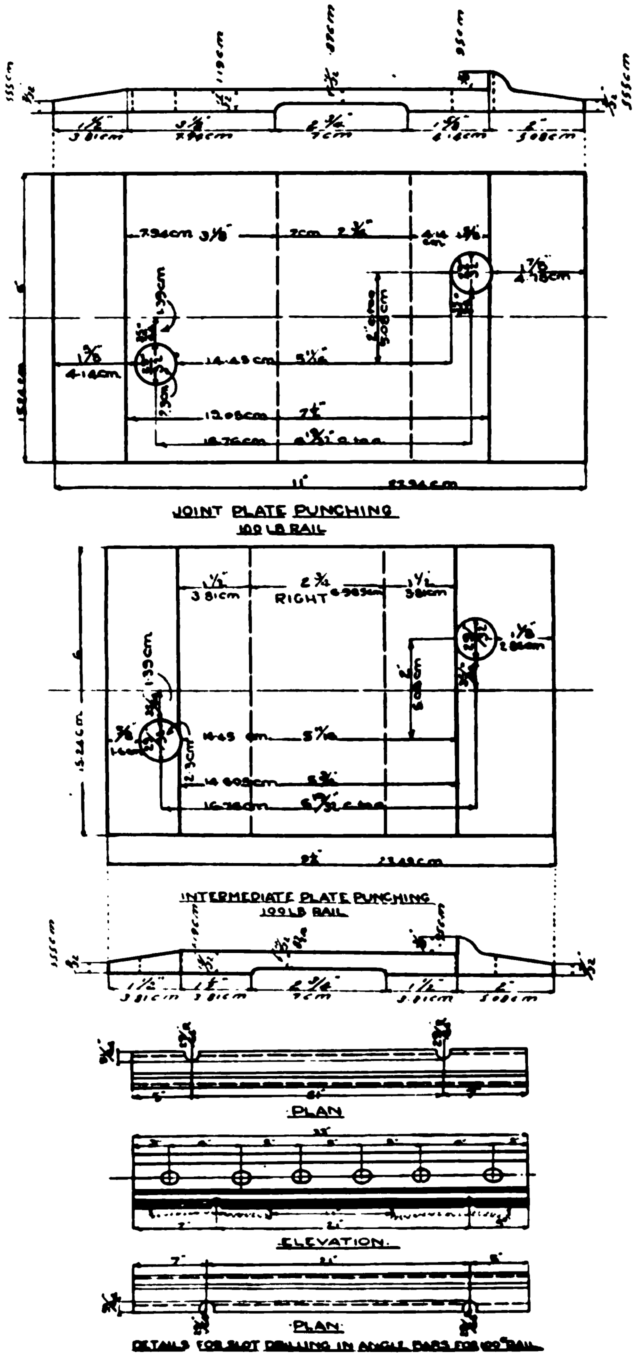

Steel Bar 1" diam.
TEMPLATE FOR ADZING TIES
Steel Bar 1" diam
TEMPLATE FOR BORING HOLES.
NOTE:-
Holes in ties to be bored
This plan to be only for track laid with 100 lb. rail.
For details of tie plates and Screw spikes see plans
Radius
Central point
Hole
Rivets
P. C. C. & St. L. Ry
PITTSBURGH DIV.
DETAILS OF TEMPLATES
FOR PREPARING TIES
TO BE USED WITH SCREW SPIKES
Scale as shown
Office Eng. M. of W.
DETAIL OF TEMPLATE FOR BORING HOLES.





DETAILS FOR TEST OF WOOD SCREWS WITH THIOLLIER'S HELICAL LINING.





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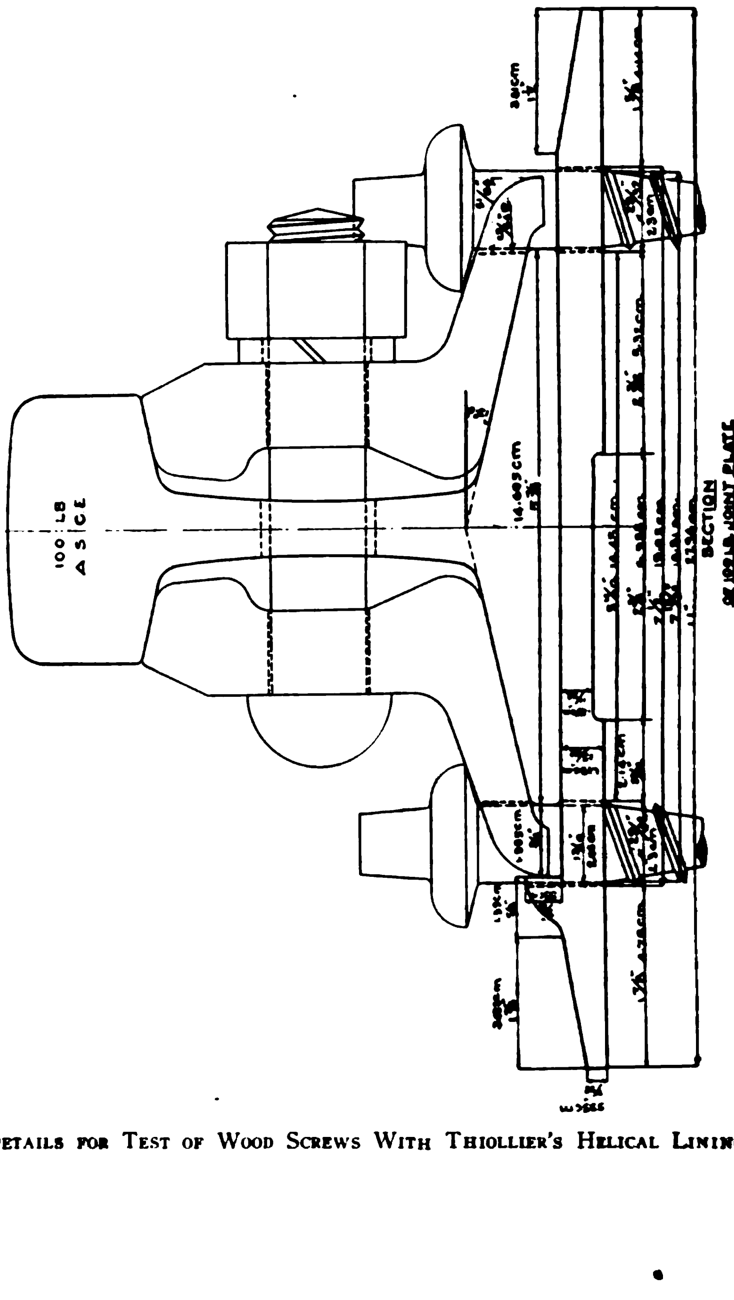

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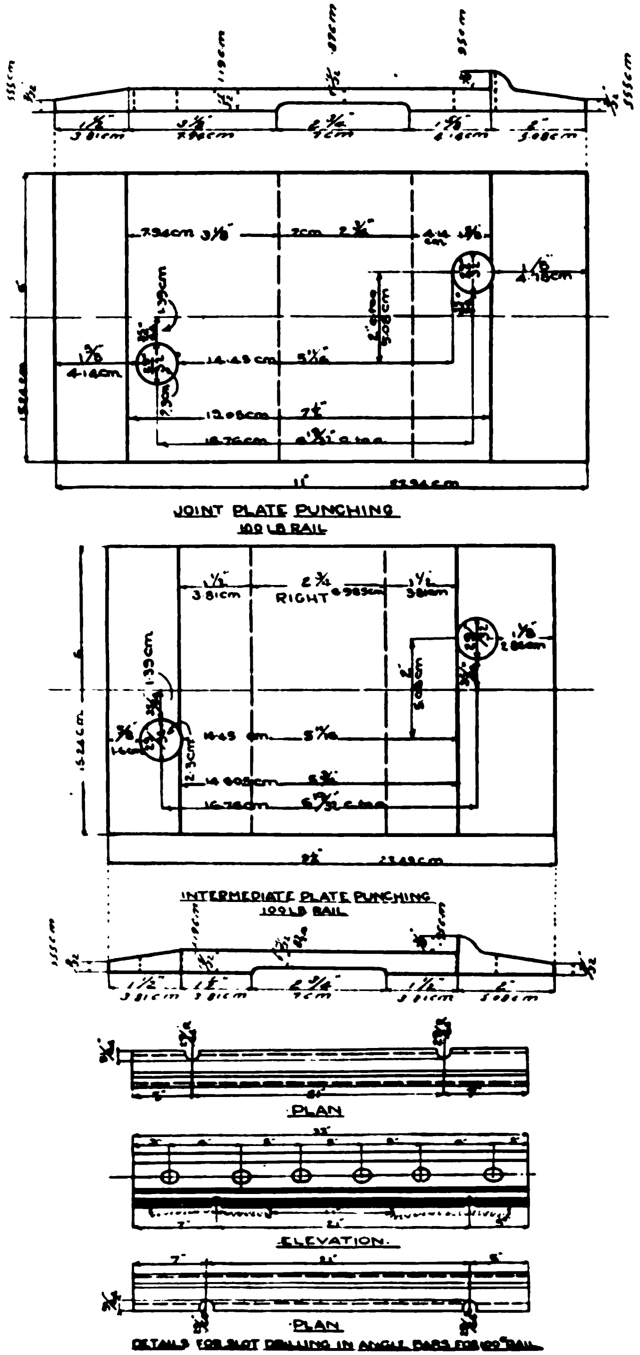

DETAILS FOR TEST OF WOOD SCREWS WITH THIOLLIER'S HELICAL LINING.

CONCERNING RAILROAD BRIDGES MOVABLE IN A VERTICAL PLANE.

By B. R. Leffler,
Engineer of Bridges, Lake Shore & Michigan Southern Railway.

As soon as an additional track is added to an existing double-track railroad, it becomes necessary to consider bridges movable in a vertical plane.

The undesirable center pier, the nearness of other bridges, and the desired boat and wharf space near the bridge site, are other factors which compel the use of this type of bridge instead of the horizontally rotating kind.

It is our purpose to consider the kinds of movable bridges now in common use. A set of specifications* is presented. Tables showing weights are given. Unusual kinds will not be considered.

Bridges, movable in a vertical plane, may be divided into two classes, viz., the Vertical Lift and the Bascule. In the vertical lift, the moving span takes successive positions similar to an elevator in a building. The bascule rotates about an horizontal axis, which is at right angles to the track.

In the vertical lift, the moving span is usually supported by wire ropes, attached to counterweights. For light spans, such as used over narrow canals, counterweight chains have been used. Sometime ago, the writer jointly considered a parallelogram mechanism as a lift for each end; this mechanism is similar to that used for some trunnion bascules.

In the bascule, the moving span may be attached to the counterweight by wire ropes; but the usual construction consists of rigid members throughout.

The bascule may be divided into two classes, viz., the trunnion type, in which the span rotates about an axis of a fixed trunnion, and the rolling type, which rolls lengthwise of the track. The latter type may also rotate about a trunnion axis as the bridge rolls.

In the selection of a type, the following views should be taken: First, the requirements of the location; second, the mechanical details and features. Referring to the first, the following points are important:

(1) The length of moving span.
(2) The vertical clearance above water.
(3) The character of the foundations.

*A previous draft of the specifications appeared in Vol. LXXVI of the Transactions of the American Society of Civil Engineers. The major part of the specifications has been adopted by the Isthmian Canal Commission for a bridge across the French Canal at Cristobal. (See I. C. C. Circular No. 785.)

(4) Skew or square channel crossing.

(5) The erection difficulties with special reference to the existing structure, and river and rail traffic.

(6) The number of times the structure is to be operated per annum.

(7) The possibility of a future rise in the level of the railroad tracks.

After considering a few of the above points, some of the mechanical features will be taken up.

It is not advisable to lay down fixed rules. Bridges of this kind are in a process of development. Things which ten years ago were considered impossible have been accomplished lately.

Longer spans of the vertical lift can be built, as compared with the single-leaf bascule. The great weight of the moving span, effect of wind, and narrowness of span, are the things which limit the length of the bascule.

The span weight, in the vertical lift, may become too great for the counterweight rope connections and number of ropes practicable.

The recently constructed bascule for the Baltimore & Ohio Railroad at South Chicago is a double track span of 235 ft., Cooper's E-50 loading.

The double-track vertical lift at the crossing of the Pennsylvania Lines over the South Branch of the Chicago River, now being constructed, has a span of 273 ft.

For the present, the following maximum approximate lengths are recommended for double-track structures and Cooper's E-60 loading:

Bascule, single leaf	260 ft.
Vertical Lift	350 ft.

For single-track structures, with trusses about 17 ft., center to center, a span of 200 ft. is about the limit for bascules.

By using nickel steel, the weight of the span can be made about 20 per cent. less than a carbon steel one.

On account of its better anchoring qualities, the trunnion type of bascule is better for the long-span bascules.

The effect of wind on long bascules is important. There is a tendency to specify too high a pressure. A pressure of 8 lbs. per sq. ft. means, according to the formula, $P = 0.0032\,V^2$, a wind velocity of 50 miles per hour. Vessels would hardly navigate in such a wind.

A pressure of 8 lbs. per sq. ft. for the span in motion, and 15 lbs. for any stationary open position of the span, should be enough for designing the machinery.

The effect of wind on the vertical lift is often ignored. The wind does not always blow horizontally. At least 2½ lbs. per sq. ft. should be taken on the horizontal surface. The effect of the wind, on the side of the span, should be considered, as it produces friction, during motion, on the sides of the tower.

The vertical clearance is important. While the vertical lift has the advantage over the bascule for long spans, the bascule has the advantage for high clearance over the channel. Each foot added to the towers of a vertical lift increases the cost.

Up to this time, no information was available to show the effect of height of towers on the cost. Tables 1 and 2 show the weights of various spans. Using these tables, the following demonstration concerning the height of towers in vertical-lift bridges is given. Proposition: Given a location where the conditions are such that either a bascule or vertical lift is suitable, which is the more economical?

The following assumptions are made: First, that the moving spans, in both types, are of equal weight and length; second, that a fixed ratio exists between the pound prices of the various parts.

In addition to the symbols given in Table 1, let C_1 be the weight in pounds for concrete counterweight for the bascule and C_2 that for the vertical lift. As found in the usual designs, approximately,

$$C_1 = 2.6W,$$
$$C_2 = 1.2W,$$

A cubic yard of concrete is assumed to weigh 4,000 lbs. and cost $12.00.

Using the symbols found in Table 1 for a square-ended bridge, we can write

$$0.97Wp + (0.3)(2.6W) + \frac{9p}{4}(0.18W) = \frac{pHW}{175} + p\frac{7}{2}\frac{WH}{3000} + \frac{9p}{4}\left[0.16W + \frac{Wd}{80} + \frac{3W}{100}\right] + 0.36W.$$

Simplifying and assuming p equal $4\frac{1}{2}$ cents and $d = 15$, $H = 88$ ft. This means that for any length of span for which a bascule can be used, say up to 260 ft. and other things equal, the bascule is the cheaper in first cost for all heights of vertical-lift towers above 88 ft., measured from base of tower to center of sheaves.

For very low lifts, such as is found over canals, the vertical lift is the cheaper.

The foregoing is based on vertical lifts having towers with 4 posts and 4 sheaves, and for double-track bridges.

The above slightly favors the vertical lift, because no account is taken of the variable counterweight chain which should be used to balance the wire rope, but which chain is not often used. Neither is a capitalized cost for wire rope renewal included.

An examination of Table 1 shows some interesting matter. For instance, in terms of cost, the counterweight ropes equal 23 per cent. of the span, for towers 200 ft. high. The sheaves, for a diameter of 15 ft., cost 45 per cent. of the span. The towers, for a height of 200 ft. cost 15 per cent. more than the span.

TABLE I—COMPARISON AND FORMULAE FOR VERTICAL LIFT SPANS.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21.
Items	Location	Span.	Height of Towers	Weight of Span not incl. Deck.	Weight of Deck.	Floor in Towers.	Towers exclusive of Floor	Sheaves and Pedestals.	Cwt. Cables and Sockets	Balance Bars etc.	Part of (5) due to L.L.	Machinery	$\frac{5+6}{3+4}$	$\frac{5+6-10}{3+4}$	$\frac{12\times100}{Ht. of T.}$	$\frac{13\times100}{Ht. of T.}$	$\frac{7}{3+4}$	$\frac{8}{3+4}$	$\frac{17\times1000}{Ht. of T.}$	$\frac{9}{3+4}$	$\frac{11}{3+4}$	Remarks
1	S. Branch Chgo. Penn. R.R.	217'-4"	204'-0"	1,562,900	152,600	323,400	2,100,000	* 150,000	90,000	40,000	240,000	230,000	1.35	1.21	0.698	0.632	0.087	0.0524	0.257	0.0233	0.134	60° Skew
2	Calumet River L.S. & M.S. Ry.	208'-9"	163'-3"	1,130,000	158,000	250,500	1,317,500	◆ 268,000	72,000	38,000	160,000	217,000	1.22	1.092	0.748	0.699	0.210	0.0564	0.346	0.0295	0.170	50° Skew
3	Calumet River Penn. R.R.	209'-9"	163'-3"	1,578,000	158,000	275,000	1,755,000															
4	Calumet River 4 Tk. Struct.	210'-0"	165'-3"	2,114,000	320,000	468,000	2,126,000	300,000	140,000													50° Skew

M = Weight of Machinery
R = Cwt. Cables and Sockets.
H_1 } Height of respective towers.
H_2 } = Top of Masonry to C. of Sheaves.
S = Weight of Sheaves & Tower Machinery.
E = Equalizer Levers.
$T_1 = (5) + (6) - (10)$
$T_2 = (5) + (6) - (10)$
$W_1 = (3) + (4)$ } Includes end bearings
$W_2 = (3) + (4)$ } under movable span.
d = Diameter of Sheave.

$T_1 = \frac{H_1 W_1}{165}$ Distances in feet.
$T_2 = \frac{H_2 W_2}{149}$ Weights in pounds.

In general, for 2 Track Bridges.
$T = \frac{HW}{160}$ for about 45° skew.
$T = \frac{HW}{175}$ for square ends.
$R = \frac{WH}{3000}$
$M = 0.16W$
$S = \frac{Wd}{80}$
$E = \frac{3W}{100}$

$T = \frac{HW}{180}$ for Item #4

Let P = price per lb. of Struct. Steel.
Then $\frac{7}{2}$P = " " " for Cables & Sockets.
$\frac{3}{4}$P = " " " for E, S & M.

Item #4 in Trusses only, 470 tons Nickel Steel was used.
Item #2 " " ", 277 " " " " "
* Item #1 Cast Sheave 8' dia.
◆ Item #2, Built up Sheave 15' dia.
All items except #4 are for double track spans.
Towers have 4 Posts and 4 Sheaves.
Items #1 and #3 are for about Coopers E 60 Loading.
Items #2 " 4 " " " " E 55 "

B. R. Leffler.

TABLE 2—COMPARISON OF MOVABLE RAILROAD BRIDGES OF THE BASCULE TYPE.

	1	2	3	4	5	6	7	8	9	10	11	
Items	Kind of Bridge	Location	Span ℄ to ℄ Bearings	Wt. of Struct. Steel in Span itself	Wt. of Deck on Span itself	Wt. of Mach. & Trunnions Tread Pls.	Wt. of Struct. Steel in tower etc. cwt. trusses	Part of #7 Due to Live Load	$\frac{\#6}{(\#4)+(\#5)}$	$\frac{\#7}{(\#4)+(\#5)}$	$\frac{(\#7)-(\#8)}{(\#4)+(\#5)}$	Remarks.
	Truss	Type										
1	Strauss.	Ashtabula Harbor	159'-4"	807,000	134,000	156,877	1,049,000	£ 95,000	0.168	1.115	1.014	2 Track Lift.
2	Strauss	Buffalo Creek	129'-9"	547,600	110,932	91,536	698,242	⊕ 97,000	0.139	1.060	0.913	2 Track Lift, Skew.
3	Strauss	Portage River.	118'-0"	1,022,865	197,224	167,993	1,072,883	x 140,000	0.138	0.88	0.765	4 Trk. Lift. Single Leaf.
4	Scherzer	Buffalo Creek.	165'-0⅝"	780,200	139,000	* 88,000	1,064,867	90,000	0.096	1.159	1.060	Nickel Plate 2 Trk.
5	Scherzer	Cuyahoga River.	160'-0"	624,796	135,000	* 85,000	786,950	75,000	0.112	1.036	0.940	Nickel Plate 2 Trk.
6	Strauss	San Pedro	187'-6"	1,061,400	158,000	194,000	1,284,515	95,000	0.159	1.054	0.96	2 Track.
7.	Strauss	So. Chicago	235'-0"	1,277,000	197,000	261,000	1,313,000	103,000	0.177	0.890	0.82	2 Trk. B. & O. Ry.
	Average omitting Item #3								0.141	1.053	0.951	
	Recommended average								0.180	1.06	0.97	
	Girder	Type.										
8	Scherzer	Peekskill.	67'-0"	254,600	67,000	22,500	226,900	11,100	0.07	0.707	0.672	2 Track
9	Scherzer	New Hamburg	50'-0"	139,000	50,000	22,600	178,900	29,000	0.12	0.946	0.794	2 Track operated by gas engine

Items 5 & 7 for Coopers E 50
Item 9 for Coopers E 40
Other Items for Coopers E 60
Weight of moving leaf in column 4 includes bearing pedestals under leaf.

*. Wt. of Machinery & Track Plates.

£ 80,000# = Tower Floor System
75,000# = Part of 80,000# due to Train Load
20,000# = Wt. on tower truss " " "

x 154,000# = Tower Floor System.
140,000# = Part of 154,000# due to Train Load

⊕ 80,000# = Tower Floor System.
75,000# = Part of 80,000# due to Train Load
22,000# = Wt. on Tower Truss " " "

B. R. Leffler

Some may object to assuming the weights of the moving spans as being equal, because, in the vertical lift, a simple span is found for all loads, while in a bascule, the span is simple only for train load. Hence some reversal of stress may be found in the bascule. Some figures, made by the writer, indicate that there is little difference. The vertical lift usually has its operating machinery and house on the center of the span. This extra weight, amounting to almost half the weight of a locomotive, for long double-track spans, requires extra metal in the span.

The superstructure for the bascule is heavier than that of a vertical lift. However, the vertical lift requires large foundations at both ends, the bascule only at one end. Hence, even for the greater weight, the foundation for the bascule costs no more than for the vertical lift. It is usually cheaper to build one large cofferdam than two slightly smaller.

On account of the counterweight rope connections, considerable height of tower, above the fully open position of the span, is necessary to keep the deviation of the ropes from the vertical as small as possible. The deviation also increases with the diameter of the sheave.

A large diameter of sheave is desirable. It reduces the movement of the individual wires, and of the rope on the sheave, also the bending of the wires. The life of the rope is thus prolonged.* The diameter of the sheaves in the Halsted Street lift is 90 times that of the wire rope.

For soft ground, the vertical lift is at a disadvantage. It is essential to the success of this type that the towers maintain their original vertical position, and are not pushed toward the channel, as is sometimes the case with masonry built on piles.

For the bascule, founded on a monolithic mass of concrete, a small movement of the mass as a whole cannot cause a relative displacement, or twisting, of the superstructure.

For either type, the concrete mass should be built as a monolith, heavily reinforced throughout, and envelop the pile heads. To insure as much lateral resistance as possible, the piles should be well driven and cut off below the river bottom.

The rolling type of bascule is at a disadvantage in soft ground. For this type, the whole moving mass occupies successive positions. Of course, the foundation must be good for any position.

The erection difficulties are peculiar to each site. The bascule may be erected in the open position, allowing trains to pass through while the work is in progress. The vertical lift does not allow of such easy erection. Space and time are too limited to cover all points pertaining to erection. Each site must be studied by itself.

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*For a discussion of the effects of bending of wire rope over sheaves, see Unwin's Mach. Design, Part I, Ed. 1909, Arts. 312 and 314.

The number of times the structure is to be opened is important. A movable bridge is a machine; if used enough, parts will wear out. Many movable bridges are successful because they are seldom operated.

In the rolling bascule type, the built-up roller and track girder loosen where the heavy concentration occurs.

A bridge seldom operated is usually poorly lubricated. For such a condition a rolling type, without trunnions, has advantages.

In the vertical lift, depending on the number of operations and character of rope lubrication, the ropes will require renewal.

For a bridge that is seldom opened, care must be taken to see that the ropes are not allowed to rust into a solid rod. This has happened to elevator ropes in buildings.

As for the trunnion type, the history of the Ferris Wheel shows that this type, with proper lubrication and design, should last many years under hard service.

The vertical lift is suitable where there is to be a future rise of the tracks. It may be designed to fit either grade. Where there is a combination of upper and lower decks, as in the Kansas City Bridge, the vertical lift is specially fitted, in particular if the upper deck is fixed. For high-speed railway traffic some forms of deck bascules are not adapted; the vertical lift is better. However, a deck bridge is seldom necessary or desirable.

The mechanical features are fairly well covered in the specifications. However, some of the main points will be briefly considered, taking each type.

In the vertical lift, small sheaves should be avoided. Some mechanical engineers, in order to save material and space, use too small sheaves.

If the diameter of the sheave is about 90 times that of the rope, and if the rope is kept well lubricated, it should be good for 350,000* passes over the sheave; for poor lubrication, this may drop to 75,000.

Taking 300,000 passes as a safe basis, this would mean, for a bridge having about 20 openings a day, a life of about 20 years for the ropes. An opening requires two passes.

Counterweight ropes are attached to the counterweight by means of a sort of whiffle-tree affair. Each small bar has two ropes attached. On account of it being impossible to put the pivot of the bar on a line with the points of attachments, the ropes are not equally stressed for all positions of the bar. For practical purposes, the stresses are about equal. However, the whiffle-tree is somewhat cumbersome.

For conveying the electric current to the motors on the vertical lift, trolley wires must be used running nearly the full length of the towers. It may be necessary to use long flexible cables, one

*See Unwin's Machine Design, Part I, Ed. of 1909, Art. 311.

end of each being attached to the moving span, the other to the tower. These long loose conductors are objectionable. The vertical lift does not allow of a simple circuit for conveying current to the motors.

As usually constructed, the counterweight ropes in the vertical lift are not balanced for all positions. Enough counterweighting is used, so that the ropes and span are balanced when the span is half way up.

For a long span, having a large number of openings of small lift per day, the unbalanced ropes will cause a relative large consumption of power, as compared with a bascule.

As an example, a vertical lift across the Cuyahoga River, at Cleveland, Ohio, on the Lake Shore & Michigan Southern, would require a maximum lift of 124 ft. The number of lifts would be about 100 per day. Half of the openings would not exceed 22 ft. The unbalanced ropes, for each start of opening, would be about 40,000 lbs. Of course, this extra load must be taken by the motors.

For the vertical lifts on the Lake Shore & Michigan Southern Railway at South Chicago, the writer had the ropes balanced for all positions of the span.

Looking at the rolling bascule, the most difficult part is the roller. Our knowledge of the stresses in a heavily loaded roller is almost nothing. The little we have is based on experiments made on small solid rollers. In most of the rolling bascules, as now built, the roller and track girder are built-up affairs. The life of such parts depends largely on careful designing and workmanship. There seem to be no well-defined rules for designing built-up rollers and track girders. From a designing standpoint this is a serious defect.

In the Indiana Harbor bridges, on the Lake Shore & Michigan Southern Railway, a full roller, composed of a cast-iron center and steel tire, was used. In about 5,000 openings of the bridges, the tire loosened. These rollers were replaced by solid vanadium cast-steel ones, which seem to be successful.

Experience seems to show that a built-up roller is not entirely successful. Wherever possible, solid cast-steel rollers, or parts, should be used. The rollers should travel on a solid cast-steel track. The metal should be of vanadium, or chrome steel.

In the trunnion bascule, and in the vertical lift, an important feature is the lubrication of the trunnions. The grooves for the lubricant should be large, have beveled edges, and allow of being easily cleaned. Helicoidal grooves should not be used.

For a lubricant, the writer has found Mexican Cup Graphite good. The grease does not harden in cold weather. It will cake, if allowed to remain too long in the grooves, due to the oil drying out. The grease can be forced into the grooves, while the bridge is in motion, by a pump which is composed of a cylinder and a piston operated by a screw.

All parts of the trunnion bascule can be designed by well-known principles. This is specially important for large structures.

The parts of the vertical lift can be designed by safe methods. However, there are differences of opinion regarding the design of wire rope for bending over sheaves. The writer does not believe it is safe to depend upon so-called practical experience derived from elevator or mine hoist practice in designing wire ropes.

The movements of a trunnion bascule are precise. The rolling bascule, like a rocking chair, tends to roll unequally, and consequently the free end must be forced into its closed position by the guides and teeth in the tracks.

The operating machinery is usually located on the moving span. This is objectionable, because the support is not firm. In the vertical lift it is necessary to have the machinery thus located, but in the bascule it may be located on the tower.

It is better to have the machinery located on the tower for the following reasons:

(1) The supporting structure can be made firm. This cannot be done if the location is on the portal.

(2) A roomy house can be built to protect the machinery.

(3) The wire circuits, conveying power to the main motors, can be made stationary throughout. When the machinery is on the moving span, these wires and their conduits are subject to bending.

The circuit for conveying power to the machinery on a vertical lift are bound to be cumbersome on account of the machinery being on the moving span.

(4) The machinery, in bascules, can be readily inspected, and observed while in motion.

(5) The oil cups retain their contents; this is not always the case in bascule bridges when the machinery is on the leaf.

It is usually assumed that the rolling bascule takes less power to operate than the trunnion. This is true until the permanent deformation in the rollers and track becomes too great. In one case known to the writer, it takes considerable extra torque to close the bridge on account of this deformation.

The trunnion bascule requires no more power, on account of friction, than a horizontally rotating bridge. Yet engineers do not hesitate to use the latter.

If the machinery is designed for braking effect and to hold the span against wind, it should be no lighter for the rolling bascule. It is well to remember that friction is not always a bad thing; it is very necessary for controlling the moving span. A brake is usually a device for using friction, and hence trunnion friction is valuable to some extent.

However, it must be granted that trunnion friction requires some extra power.

In the vertical lift, rope bending is another element of frictional loss.

An important detail is the connection between the shore rails and span rails. Rails with long mitre joints are used; this joint will not stand up under heavy and frequent wheel loads.

Sliding locks are used; these require extra machinery. To do away with the machinery, the writer devised a stationary lock, which has guides for seating the span rail, and a lock bar for holding the rail in place. The lock bar is made part of the interlocking apparatus.

On the outside of the rails is a replacable wearing strip, which carries the wheels across the rail gap. The body of the lock, which receives the blow and to which the wearing strip is attached by a dovetail joint, is a solid casting surrounding the lower part of the span rail and shore rail. On account of the false flanges on wheels, this lock does not make a smooth riding track, but the same roughness is found in the sliding lock; there is no more roughness than is found at frogs. The heads of the rails should be cut back to a width of 1¾ in.; this places the wearing strip close to the gage side of the rail and insures the wheels being carried by the strip. The rails should be reinforced by side pieces riveted to the web.

The material in the wearing strip should be oil-tempered crucible steel, with three-quarters of one per cent. carbon. The material should be tempered very hard; if this is properly done, the strip will take a hard, glossy finish under traffic. The strips under Lake Shore & Michigan Southern Railway traffic will last from 18 months to two years.

There has just been completed a single-track, double-leaf trunnion bascule at Sault Ste. Marie, having a span of 336 ft. The success of this structure will depend on the reliability of the center lock. The writer waits with considerable interest for the practical demonstration of this structure through a number of years of service, and if it continues to operate satisfactorily it will solve the problem of long bascules.

The writer has called attention to some of the general points and mechanical features. A few miscellaneous points will now be taken up.

Table 1 contains weights of several vertical lifts and purely empirical formulas for weights. All of the structures are skew-ended, and the towers have 4 posts and 4 sheaves each.

For square ends the writer has given a modified formula for tower weight. The decrease in weight is found chiefly in the bracing in two of the vertical planes.

Table 2 shows weights of bascule bridges.

In these tables the various weights are compared with the weight of the moving span including the deck, but not any machinery.

In some vertical lifts, with approach spans, each tower has two

vertical posts and two sheaves. The vertical posts are held in position by a long inclined member, reaching from the top of the post to the approach span. Until further knowledge is available, the following formula is suggested for tower weights:

$$T = \frac{WH}{200}.$$

For towers with only two sheaves, a greater load is carried by each sheave, as compared with a tower having four sheaves. The following formula is suggested as a rough approximation for sheave weight:

$$S = \frac{Wa}{57}.$$

Item 4, in Table 1, gives the weights for a four-track structure. The weights were figured from complete proposal plans. A two-structure design, item 2, was considered the better and adopted instead.

Item 3, in Table 2, is for the first four-track leaf to be built. The photograph shows the structure. There are two trusses and two plate girders, each of which rotates about its own trunnion.

Someone has said that it is easy to put two points on a straight line, but that the trouble begins when three or more are to be put on. To make the four carrying spans rotate about four trunnions is a similar problem.

Torque curves, for item 3 of Table 2, are shown. The curves are dependent on the wind pressure, frictional resistances, etc. They give a complete picture of the work to be done by the motors. These curves are useful for determining the storage-battery capacity, and for checking up the design of the machinery. These curves should be drawn up by the designer and subsequently checked by the fabricating contractor.

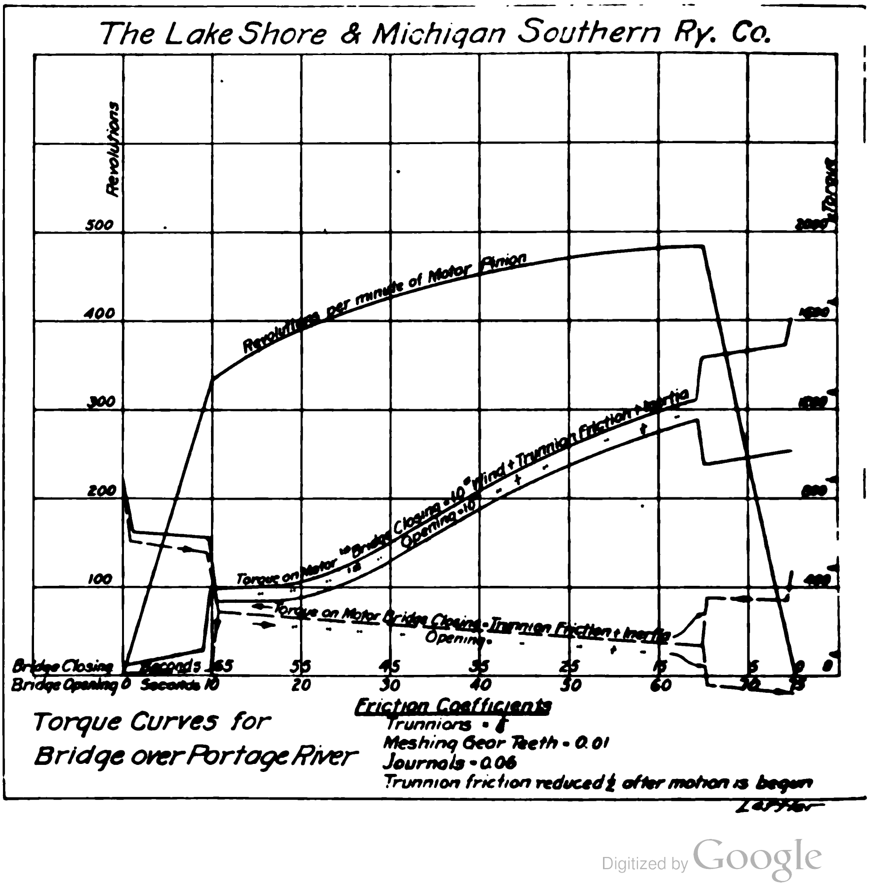
In Table 2 the writer has given a recommended machinery weight of $0.18W$. This is about 20 per cent. greater than the average. It is the opinion of the writer that bascule bridge patentees specify light machinery; under competition this is to be expected. The writer has had one structure in which the rack and pinion were broken by excessive braking.

The following suggestions are made regarding the actual work of designing and installation. The first essential is a good set of specifications. Relative weights are necessary.

All patentees are not suitable parties for writing specifications or making comparisons of the various types. The patentee should furnish weights and state his practices with reference to his own type.

In this paper an attempt is made to set forth some information and practices necessary for the proper selection and design of a structure. More information is needed. The field of bridges, movable in a vertical plane, has been hardly touched in a professionally technical way; it has been largely exploited.

BASCULE BRIDGE OVER PORTAGE RIVER, PORT CLINTON, OHIO.



If the railway company has a first-class engineering organization, the selection of the type, direction of the designing and installation should be done by the organization. Otherwise, an able, disinterested Consulting Engineer should be engaged. The actual designing should be done by the patentee. The function of the railway organization should be chiefly critical and suggestive.

The fabrication and installation should be done by the same contractor. His contract should cover all work up to and including the operating switchboard. There should be a separate contract for installing the power equipment.

All electrical apparatus should be of a large size to insure mechanical strength, especially circuit breakers, knife switches and fuse clips.

It is desirable to have the contractor keep an expert electrician, or mechanic, on the structure for a period of 90 days after the structure has been formally accepted and put into operation. This man is to observe and correct any defects which may arise, and instruct the railway company's forces in the handling of the structure.

Referring to the specifications, the writer is indebted to Messrs. Waddell and Harrington, Consulting Engineers, for much of the matter covering workmanship and material for wire ropes; and to others for some of the other matter. The writer is also indebted to the New York Central Lines Bridge Engineers' Committee; this committee is now preparing specifications for movable railroad bridges in general. The index was prepared by Mr. C. A. Knieling, one of the writer's assistants.

SPECIFICATIONS FOR RAILROAD BRIDGES MOVABLE IN A VERTICAL PLANE.

CONTENTS.

SPECIFICATIONS FOR RAILROAD BRIDGES MOVABLE IN A VERTICAL PLANE.

Scope.

1. These specifications are intended to cover bascule bridges, which are such as rotate about a horizontal axis; and vertical lifts, which are those in which successive positions are parallel.

Deck.

2. The Contractor shall place and permanently fasten all ties, rails, guards, and other deck material. Usually, the Railway Company will furnish all of the deck material except rail locks, rails which must be fabricated to fit locks, and special devices to hold the deck in place.

Responsibility.

3. If complete general proposal plans are furnished to the Contractor, he shall be responsible for only the material and character of the workmanship and installation. However, for any parts of the design not covered by the proposed plan, and for which the Contractor is to make a design, he shall be wholly responsible for those parts.

Electrical Equipment.

4. Unless otherwise specified, the electrical equipment shall include all electrical parts up to the switch-board and including the switch-board. Electric equipment carrying the current to the switch-board from the source of power will be covered by separate contract.

Specifications.

5. The specifications of the New York Central Lines for Steel Railway Bridges, for 1910, shall apply to movable bridges, except as noted herein. (35), (39).

MANNER OF BIDDING.

Parts Classified as Machinery.

6. Drums, cylinders, eccentrics, pivots, trunnions and their cast supports, shafting, pistons, gear wheels, racks, boxes, bearings, couplings, clutches, discs, cast sheaves and wheels, worm gearing, valves, pins about whose axis the connecting members rotate, whistles, ram screws, end bridge locks, rail locks, indicators, cranks, axles, hooks, wrenches, and similar parts of machinery which require machine-shop work, shall be classified as machinery and be paid for at a common price per pound. Electric motors or other prime movers, pumps and compressors are not classified as machinery. (11), (17).

Sheaves.

7. Sheaves, such as used with counterweight ropes, whose webs and diaphragms are built up by means of plates, angles, and rivets, shall be paid for at a separate price per pound of finished weight, including hubs and fastenings to trunnions.

Air Compressors, Boilers.

8. Air Compressor tanks and steam boilers, their fittings and piping, shall be paid for at a separate lump-sum price.

Wire Ropes and Cables.

9. Wire ropes and cables and their sockets shall be paid for at a separate price per pound.

Pins, Levers, Etc.

10. The pins, equalizing levers, and cable attachments to the trusses and counterweights shall be paid for at a separate price per pound.

Structural Steel Parts.

11. Structural steel supporting the machinery proper, counterweight frames, counterweight trusses, steel in operator's house, towers, and links, shall be classified as structural steel, and be paid for at the same price per pound as for the span itself. Attached machine parts, such as sleeves, bushings, etc., shall be weighed separately and classified as machinery. (6).

Operator's House.

12. The operator's house, except for the structural steel therein, shall be paid for on a lump-sum basis.

Structural Steel.

13. Structural steel which can be fabricated by the common shop methods, as punching, reaming, drilling, shearing, planing, etc., as is usually done for stationary structures, shall be classified as structural steel, and be paid for at the same price per pound as for the span itself.

Segmental Girders.

14. Segmental girders in rolling bascule bridges and the horizontal girders on which they roll shall be paid for at a separate price per pound. This does not include any bracing, floor system, or other structural members which may be attached. Tread plates shall be included.

Hand Rail.

15. Hand rail shall be paid for at a separate price per pound.

Electrical Equipment.

16. Electrical equipment, such as wiring, switch-boards, controllers, lights, blow-outs, cut-offs, solenoids, switches, motors, etc., shall be paid for on a lump-sum basis.

Engines, Etc.

17. Internal combustion engines, steam engines, pumps and compressors shall be paid for on a lump-sum basis.

Counterweights.

18. Cast-iron and scrap metal used in counterweights shall be paid for at a separate price per pound.

19. Concrete in counterweights shall be paid for at a price per cubic yard in place.

Extra Parts, Etc.

20. It is to be understood that if any extra parts are needed, or any question arises, all difficulties shall be settled on the pound price basis as quoted and accepted for the parts in question.

GENERAL DETAILS IN DESIGNING.

Design, Type of Moving Spans.

21. The moving span, when closed, shall act as a simple beam or span under the live load. The live load reactions shall be vertical. Bascule bridges shall be single leaved.

Self-Centering Devices.

22. Self-centering and seating devices shall be used on the free ends of the moving span. Holding and forcing-down devices shall be used for the free ends of each truss.

Rail Locks.

23. Designs for bridging the gap between the shore rails and moving rails shall be furnished by the Railway Company. Loose rails will not be allowed.

Air Buffers.

24. Air buffers shall be furnished at the free ends of the moving span. The packing rings in the pistons of the buffers shall be of cast-iron or other suitable metal; fiber or leather packing will not be allowed. At least three rings shall be used. (156).

Counterweights.

25. The counterweights shall be easily adjustable. Usually, this shall be done by adding or taking away cast-iron parts, or small concrete blocks.

Stairways.

26. Metal stairways with 1½-in. pipe hand-rail shall be provided for access to the machinery, trunnions, and counterweigths. The pipe shall weigh 2.68 lbs. per ft.

Girders in Rolling Bridges.

27. The reinforcements of webs in the segmental girders and track girders of rolling bridges shall be symmetrical about the center planes of the webs. The center planes of the segmental webs shall coincide with the corresponding center planes of the webs of the track girders. That part of an outstanding leg of an angle, which is beyond the outside face of the upstanding leg, shall not be considered as reinforcement. The width of contact between the segmental webs (including the reinforcements) and the back of the tread plates, shall be equal to the width of the corresponding contact in the track girder.

Coefficients of Friction for Moving Span and Attached Parts.

28. In calculating the resistances to be overcome by the machinery, the resisting forces shall be reduced to a single force acting between the

pinion and operating rack, or in the operating cable. In determining this force, the following coefficients shall be used in starting the span, and, except for the stiffness in cables, shall be reduced one-half after motion is begun (45):

For trunnion friction.............................. 1/8

For rolling friction of bridges having rollers with flanges or built up segmental girders..............1/12

For stiffness of wire rope per 180° of bending, d = diameter of rope, in in...................... $\frac{d^2}{3D}$

D = diameter of sheave in in.

Coefficients of Friction.

29. For a solid cast roller without flanges, in contact with one surface only, the coefficient of rolling friction shall be taken equal to $\frac{15}{1000r}$, in which r is the radius of the roller in in. If two surfaces are in contact, use $\frac{3}{100r}$.

30. In figuring the machinery losses between the operating rack or operating cable and the motor, the following coefficients shall be used:

For the efficiency of any pair of gears, journal friction not included.................................0.99

For journal friction...............................0.05

Losses in a worm gear for an angle of thread of 20 degrees or more..................................0.30

31. For sliding friction between plane surfaces intermittently lubricated, such as guides on tower posts, the coefficient of friction shall be taken equal to 0.08.

Time to Open.

32. The time to open the bridge after the ends are released shall be approximately as specified on the proposal drawing.

Inertia.

33. The force necessary to overcome the inertia and produce acceleration and retardation for the time of opening, shall be considered. The machinery shall be capable of stopping the bridge in six (6) seconds; for this purpose the coefficient of friction in the friction brake shall be taken at not less than 25 per cent. (37), (38), (158), (159), (160), (161).

Impact in Structural Parts.

34. The dead-load stresses in the moving structural parts for the various positions of the open bridge shall be increased 25 per cent. as allowance for impact. For stationary structural parts (as towers and supporting girders in rolling bridges) which support the moving structural parts, the static stresses caused by the moving parts shall be increased

15 per cent. for impact. These impacts shall not be taken in conjunction with the train-load stresses.

35. In structural steel parts, where a percentage of the dead load or static stress is added for impact, the unit stresses for stationary structures shall be used; the impact percentages are an allowance similar to that provided by an impact formula for stationary railroad bridges. (5). See paragraph 41 of the 1910 specifications.

Reversal of Stress.

36. In structural members subject to reversal on account of the motion of the span, the effect of reversal shall be neglected. The member must be designed for the stress giving the larger section. For riveted connections, the number of rivets shall be increased 25 per cent. over that required for the static stress plus impact stress.

Impact for Machinery Parts, Etc.

37. The allowance for impact in trunnions, cables, cable attachments, machinery parts, and structural parts supporting the machinery is taken care of by lowered unit stresses. (159), (160), (161).

Wind Pressure.

38. In proportioning the machinery for wind load the following cases shall be considered; first, for any stationary open position of the span, assume 15 lbs. per sq. ft. on the exposed surface of the span as projected on any vertical plane; second, for moving the span in the specified time of opening, assume 8 lbs. per sq. ft. on projected area. (28), (33), (37), (41), (45).

39. The structure shall be proportioned to resist a wind pressure of 15 lbs. per sq. ft. on the exposed surface as projected on any vertical plane for any open position of the span; and for a wind pressure of 25 lbs. per sq. ft. when the span is in the closed position. (5), (41).

Least Wind Pressure.

40. The least wind pressure to be assumed on the floor of the moving span shall be 2½ lbs. per sq. ft. for any position of the span. For the vertical lift, this shall be taken as acting throughout the movement.

41. On the ordinary open floor bridge with ties, the exposed surface to wind shall be taken equal to 85 per cent. of a full quadrilateral, whose width is the distance center to center of trusses and whose length is that of the moving span.

Detail Drawings.

42. The Contractor shall make complete detail drawings of the machinery, so that any other shop can take them and duplicate the machinery. No reference to patterns or individual shop practices will be considered in lieu of the complete drawings. These drawings shall show a general outline of the assembled machinery. The drawings shall be made on tracing cloth, each sheet 24 in. by 36 in. in outside dimensions. These drawings shall become the property of the Railway Company on the completion of the job.

Outline Drawing of Machinery.

43. The Contractor shall furnish an outline drawing of the machinery on which are shown the forces acting on the gear teeth, the twisting moment and bending moment on shafts, and other necessary information for checking the strength of the machine parts. A tabulation of the formulas and methods of calculation shall be shown complete enough to allow them to be checked.

Torque Curves.

44. The Contractor shall show by a drawing of curves the torque to be exerted by the motor or prime mover, as follows:

(1) A torque curve for acceleration and retardation.

(2) A torque curve for the frictional resistance.

(3) A torque curve for any unbalanced condition of the structure.

(4) A torque curve for the wind load.

(5) A torque curve showing the greatest combination of resistances acting at any one time.

Starting Friction.

45. In figuring the friction at starting (this being twice the running friction), no acceleration of the moving mass shall be considered. This friction shall be considered as reduced to the running friction in the first second after the power is applied. (28).

Capacity of Wires, Etc.

46. If the Contractor is to furnish the design for the electric equipment, such as wiring, switches, etc., he shall show by a curve the current required by the motor to overcome the various resistances. This is for the purpose of checking up the carrying capacity of wires and other parts and determining the storage battery capacity.

Center of Gravity.

47. The Contractor shall check the location of the center of gravity of the moving span, including all parts attached thereto, and also the location of the center of gravity of the counterweights, including counterweight girders and trusses, by computations based on accurate weights figured from shop plans. He shall submit duplicate sketches and copies of these computations accompanied by weight bills to the Railroad Company for approval.

Hand Operation.

48. All bridges shall be equipped with hand-operating mechanism. The number of men and the time required to operate shall be estimated on the assumption that the force one man can exert on a lever is 40 lbs. with a speed of 160 ft. per minute, developing about one-fifth H.P. For calculating the strength of the machinery, the force of one man shall be assumed as 125 lbs.

OPERATING MACHINERY AND SIMILAR PARTS.

49. The parts shall be simple in design, and easily erected, inspected, adjusted, and taken apart. The fastenings shall securely hold the parts in place after they have been set.

Kind of Material.

50. Rolled or forged steel shall be used for bolts, nuts, keys, cotters, pins, axles, screws, worms, piston rods, trunnions and crane hooks, if any.

51. Trunnions, pins and shafting over 4½ in. in diameter shall be of forged structural steel. Shafting 4½ in. or less in diameter may be of cold-rolled steel.

52. Forged or cast steel shall be used for levers, cranks, and connecting rods.

53. Cast steel or forged steel shall be used for couplings, end shoes, racks, toothed wheels, brake wheels, drums, sheaves, and hangers where supported weight will cause tensile stresses. Large sheaves may be built of structural steel.

54. Pinions shall be made of forged steel and cut from the solid metal, unless pinions are too large for forgings.

55. Sockets used for holding the ends of wire ropes shall be forged without welds from the solid steel. The equalizing levers connecting the ropes to the counterweights, or moving span, shall be of forged steel.

Cast-Iron.

56. Cast-iron may be used in boxes for shafts, 2 in. or less in diameter, and which obviously carry light loads. Other boxes shall be of cast steel.

57. Cast-iron may be used in eccentrics, cylinders, pistons, fly wheels, and parts of motors which are usually made of cast-iron. Cast-iron shall not be used for any trunnion or axle supports.

Metal for Bushings.

58. Phosphor bronze, brass, and babbitt metal shall be used for the bushing or lining of journal bearings and other rotating or sliding surfaces to prevent seizing.

59. Phosphor bronze only shall be used for bushing for the trunnions of bascule and lift bridges, or in any large bearing carrying heavy loads.

60. The bushings for large bearings, such as for trunnions and similar parts, shall be held from rotating in their casings. The force tending to cause rotation shall be taken as one-eighth of the load on the trunnion or bearing, and as acting tangent to the surface between the back of the bushing and casing; this force shall not be considered as counteracted by any frictional resistances between bushing and casing. It shall be practicable to take out the bushing when the trunnion is slightly lifted.

Castings.

61. Castings which are to be attached to rough unfinished surfaces shall be provided with chipping strips. The outer unfinished edges of ribs, bases, etc., shall be rounded off and inside corners filleted.

Bolts and Nuts.

62. Bolts and nuts up to 1½ in. in diameter shall have U. S. Standard V-threads. Nuts and exposed bolt heads shall be hexagonal in shape, and each nut shall be provided with a washer. If the nut will come on an inclined surface, a special seat, whose top surface is at right angles to the bolt, shall be cast or built up to receive the nut. Bolt heads which are countersunk in castings shall be square.

63. Nuts which are subject to vibration and frequent changes of load shall have locking arrangements to prevent the gradual unscrewing of the same. If double nuts are used for that purpose, each nut shall be of the standard thickness. Nuts subject to vibration shall be further secured by split pins through the bolt.

Screws.

64. Screws which transmit motion shall have square threads.

Tap Bolts, Set Screws, Etc.

65. Tap bolts and stud bolts shall not be used, except by special permission.

66. Set screws shall not be used for transmitting torsion to shafts or axles.

Collars.

67. Collars shall be used wherever necessary to hold the shaft from moving horizontally. Each collar shall have at least two set screws at an angle of 120 degrees.

Shaft Couplings.

68. Shaft couplings, unless of the flexible kind, shall be of the flange type, or split muff with bolt heads and nuts countersunk.

69. For large shafts, couplings such as are used for rolling mill shafting may be used.

70. Couplings shall be keyed to shaftings.

Keys—Approximate Dimensions.

71. If practicable, hooked and tapered keys shall be used. The taper shall be ⅛-in. per ft. The approximate width of the key shall be one-fourth of the diameter of the shaft. The height at mid-section of tapered length shall be three-fourths of the width. The length of the hook, measured parallel to the shaft, shall be equal to the width of the key.

72. If tapered keys are not practicable, parallel faced keys of about the above proportions shall be used.

73. Tapered keys shall bear on top, bottom, and sides; parallel faced keys shall bear on sides only.

74. The length of a key shall be not less than that of the hub. The key, when driven into its final position, shall bear on the full length of the hub.

75. The foregoing dimensions are approximate. The shape of the key must be such as to have unit stresses in shear and bearing not exceeding those allowable in the table. (159).

76. If practicable, the keys and grooves shall be made so that the keys may be backed out.

77. Keys shall be sunk in grooves in both hub and shaft. The depth of a groove shall be such that the bearing will not exceed the allowable unit stress.

Set Screws, Etc.

78. Keys shall be held by set screws or equivalent means. In vertical shafts, bands clamped about the shaft, or other devices, shall be placed below the key.

Hub.

79. If practicable, the length of the hub shall not be less than two diameters of the shaft; its thickness not less than one-third of the diameter of the shaft. The hub shall have a light driving fit on the shaft.

80. The groove in the hub shall be made on the center line of an arm.

81. Hubs shall be bored truly at the center of the wheel.

Keys in Trunnions.

82. For trunnions and similar parts, which are designed chiefly for bending and bearing, the keys, key-ways, and bolts shall be designed to hold the trunnions from rotating. The force tending to cause rotation shall be taken at one-fifth the load on the trunnion, and shall be taken as acting at the circumference of the trunnion.

Journals.

83. Journals shall be proportioned to resist, not only the various stresses to which they are subjected, without exceeding the permissible fiber and bending stresses, but also to prevent a tendency to heat and seize.

84. Divided journal and trunnion bearings shall be used, and the cap shall be fastened to the base with turned bolts recessed into the base. The nuts and heads shall bear on finished bosses cast on the bearing. There shall be ⅛-in. clearance between the lining of the base and the cap or its lining to allow for expansion.

Bushings.

85. Steel bearings carrying steel shafts or journals shall be lined with bronze or brass. If shafts are 3 in. or less in diameter and of a slow motion, babbitt metal may be used. Bearings of steel on steel for moving surfaces will not be allowed.

Bearings.

86. In cast-iron bearings carrying light shafts, no lining is needed.

87. The bearings of shafts shall be placed as near to the points of loading as possible.

88. The footsteps of vertical shafts shall be of tool steel and run on bronze discs.

Lubrication.

89. Provision shall be made for the effective lubrication of journals, or any other sliding surfaces. Closed oil or screw compression grease cups shall be used. Grooves shall be cut in the surface of the trunnion to provide for the proper distribution of grease or oil. Grease and oil cups must hold the lubricant for any position of the moving parts.

Grease Grooves.

90. The grooves in large trunnions shall approximate to a **U** shape; the size shall be such that a wire 5-16-in. in diameter may lie wholly within the groove. The edge of the **U** shall be rounded to a ¼-in. radius.

91. The grooves shall be straight, running parallel to the axis of the trunnion. They shall be so located, not less than three in number, that all parts of the bearing surface of the bushing will be swept by the contained lubricant in an opening and in a closing of the bridge. The grooves must allow of being cleaned with a wire.

Grease Cups.

92. In any trunnion bearings, or similar heavy bearings, strong screw compression grease cups shall be used for the grooves.

93. Oil and grease ducts shall be so located, if practicable, that the lubricant will flow by gravity toward the bearing surface.

Housing of Sheaves. Dust Covers.

94. Counterweight sheaves shall be housed to protect from the weather. Dust covers shall be provided for principal bearings where practicable.

Shaft Supports and Couplings.

95. Line shafts, extending from the center of the bridge to the end, shall not be continuous, but shall be connected with claw couplings. Each length of shafting shall rest in not more than two bearings with the couplings close to the bearings.

96. If shaft supports are connected to the floor beam in bridges having long panels, intermediate supports shall be used. These shall be adjustable, and are intended merely to prevent the shaft from sagging.

Equalizing Gears.

97. Equalizing gears or devices shall be used to insure equal action at the pinions and operating racks.

Unsupported Length of Shafts.

98. The unsupported length of shafts shall not exceed $L = 80\sqrt[3]{d^2}$ for shafts supporting their own weight only; $L = 50\sqrt[3]{d^2}$ for shafts carrying pulleys, gearing, etc., where L = length of shaft between center of bearings, in inches, and d = diameter of shaft, in inches.

Speed of Shafting.

99. Line shafts connecting machinery at the center to that at the ends shall run at fairly high speed. The speed reduction shall be made in the machinery near the end.

Formulas for Shafts.

100. In designing circular shafting, trunnions, and axles, the greatest unit fiber stress in tension or compression due to bending and twisting shall be calculated by the following formula:

$$f = \frac{32}{\pi d^3}\left(\frac{3}{8}M + \frac{5}{8}\sqrt{M^2 + T^2}\right)$$

101. The maximum unit shear shall be calculated by the following formula:

$$S = \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$$

102. In these formulas, f = unit fiber stress in tension or compression; S = unit shear; d = diameter of shaft; M = the simple bending moment; and T = the simple twisting moment.

103. If a shaft, trunnion, or axle has one key-way cut at the section where the maximum stresses occur, f and S shall be increased one-sixth; if two key-ways are cut, increase by one-fourth. If the shaft is enlarged through the hub, this does not apply.

Minimum Shafting.

104. Shafting transmitting power for the operation of the bridge, and shafting 4 ft. or more in length forming part of the operating machinery of the rail locks and bridge locks, shall not be less than 2½ in. in diameter.

Distance Between Shaft Supports.

105. In figuring the bending moment on shafts, trunnions, and journals, the distance center to center of bearings shall be taken.

Style of Gear Teeth.

106. Gear teeth shall be of the involute type with an angle of obliquity of 20 degrees. The roots below the clearance line shall be filtered.

107. The width of the teeth may be as great as four times the pitch, but not more, except for wheels running at a very high velocity, as in motors where abrasion is to be considered.

Strength of Beveled Gear Teeth.

108. In estimating the strength of teeth in beveled wheels, the pitch at the middle section shall be taken.

Pitch Circle.

109. For the purpose of accurately setting gear teeth in the field erection, the pitch circle shall be scribed on the ends of the teeth.

Worm Gearing.

110. Worm gearing, for transmitting power, shall have an angle of thread not less than 20 degrees. The worm shall run in oil. A bronze or brass collar shall be used at the end of the worm and at the end of the wheel axle to take care of the end thrust. The wheel shall be of bronze. If a nut engages the worm, the nut shall be of bronze.

111. Worms which are to be used for actuating signals, indicators, or other minor parts may have an angle of thread less than 20 degrees.

Teeth in Worm Gears.

112. Worm wheels shall have no fewer than twenty-six teeth.

Pinion Teeth.

113. Pinions shall have no fewer than fifteen teeth.

Diameter of Sheaves.

114. For the purpose of keeping down the wear between the individual wires in counterweight rope, the diameter of the sheave shall be at least 90 times that of the rope.

Deviation of Counterweight Ropes.

115. The greatest deviation of a counterweight rope, from the vertical plane through the center of the groove, shall not exceed 1 in 40. Any deviation shall be as small as practicable.

Rope Connections.

115a. Rope connections shall be made so that any one rope can be renewed without disturbing the remaining ropes.

Safety Guards.

116. Machinery parts, near which workmen may be while the parts are in motion, shall be so designed that safety guards may be added. These guards will be furnished and installed by the Railroad Company.

Sheave Rims.

117. The cast rim of sheaves carrying wire rope shall have a deep flange so that enough rivets can be put through flange and web to carry all of the load coming on the rim into the web. The rim shall be strengthened by transverse ribs, or be made thick enough.

COUNTERBALANCING, OPERATING ROPES, AND ATTACHMENTS.

Wire Ropes and Cables.

118. Wire rope shall be made by a manufacturer approved by the Engineer.

119. The counterbalance ropes shall be made of plow steel wire and shall consist of six strands of nineteen wires each laid around a hemp center.

120. Ropes shall be laid up in the best manner and shall be thoroughly soaked in an approved lubricant during the process of manufacture.

121. The counterbalance ropes shall be made from wire which has been tested in the presence of an inspector designated by the Engineer, and which, for sizes 0.076 to 0.150 in. in diameter (the limiting values used in counterbalance ropes), exhibits the following physical properties:

(a) The tensile strength per sq. in. shall not be less than 225,000 lbs. for wire 0.150 to 0.126 in. in diameter, nor less than 230,000 lbs. for wire 0.125 to 0.101 in. in diameter, nor less than 235,000 lbs. for wire 0.100 to 0.076 in. in diameter.

(b) The total ultimate elongation, measured on a piece 12 in. long, shall not be less than 2.4 per cent.

(c) The number of times a piece 6 in. long can be twisted around its longitudinal axis without rupture shall not be less than 1.4 divided by the diameter, in inches.

(d) The number of times the wire can be bent 90 degrees, alternately to the right and to the left, over a radius equal to twice its diameter without fracture shall be not less than six. This test shall be made in a mechanical bender so constructed that the wire actually conforms to the radius of the jaws, and is subjected to as little tensile stress as possible.

Ultimate Strength of Cables.

122. The rope shall, if possible, be made in one piece. Its breaking strength, as determined by test described in paragraph 125, shall not be less than

4,900	lbs.	if	¼	in.	in	diameter
11,800	"	"	⅜	"	"	"
20,600	"	"	½	"	"	"
32,400	"	"	⅝	"	"	"
45,000	"	"	¾	"	"	"
70,000	"	"	⅞	"	"	"
79,200	"	"	1	"	"	"
100,800	"	"	1⅛	"	"	"
120,600	"	"	1¼	"	"	"
148,000	"	"	1⅜	"	"	"
173,000	"	"	1½	"	"	"
200,000	"	"	1⅝	"	"	"
230,000	"	"	1¾	"	"	"
264,000	"	"	1⅞	"	"	"
297,000	"	"	2	"	"	"
325,000	"	"	2⅛	"	"	"
374,000	"	"	2¼	"	"	"
465,000	"	"	2½	"	"	"

123. In case the physical qualities of the rope, or its individual wires, fall below the values cited above, the entire length from which the test pieces were taken shall be replaced by the manufacturer with a new length, the physical qualities of which come up to the specifications.

124. The dimensions of the sockets shall be such that no part under tension shall be loaded higher than 65,000 lbs. per sq. in. when the rope is stressed to its ultimate strength, as named above. The sockets must be attached to the rope by a method which is reliable, and which will not permit the rope to slip in its attachment to the socket.

125. In order to show the strength of the rope and fastenings, a number of test pieces, not more than 10 per cent. of the total number of finished lengths which will ultimately be made, nor less than two from each original long length, and not more than twelve ft. long, shall be

cut, and shall have sockets, selected at random from those which are to be used in filling the order, attached to each end. These test pieces are to be stressed to destruction in a suitable testing machine. Under this stress the rope must develop the ultimate strength given in paragraph 122.

126. If, in testing, slipping in the sockets should occur, then the method must be changed until slipping is avoided. The sockets themselves shall be stronger than the rope with which they are used; if one should break during the test, then two others shall be selected and attached to another piece of rope, and the test repeated; and this process shall be continued until the inspector is satisfied of their reliability, in which case the lot shall be accepted. If, however, 10 per cent. or more of all the sockets tested break at a load less than the minimum ultimate strength of the rope given in paragraph 122, then the entire lot shall be rejected.

Length of Rope.

127. The length of each rope from inside of bearing to inside of bearing of socket shall be determined, and a metal tag having the said length stamped thereon shall be securely attached to the rope.

Testing Rope Connections.

128. One-third of the wire rope connections, selected at random, shall be tested (after attachments to ropes are made) up to four-tenths of the ultimate strength of the rope. If any connection is weak, the remainder of the connections shall be tested. The weak connections shall be rejected and replaced. Not less than four connections shall be tested.

Facilities for Testing Ropes.

129. The manufacturer shall provide proper facilities for making the tests, and shall make at his own expense all the tests required. Tests shall be made in the presence of an inspector who represents the Engineer.

Shipment of Rope in Coils.

130. Ropes shall be shipped in coils whose minimum diameter is at least thirty times that of the rope, and they shall be uncoiled for use by revolving the coil, not by pulling the rope away from the stationary coil.

WORKMANSHIP.

Finish.

131. For the parts of the operating machinery of movable bridges which are usually exposed to the weather, the finish shall be confined to the bearing, rotating, and sliding surfaces, and wherever it is required to produce accurate fits and precise dimensions.

132. Equalizing levers in rope connections shall be neatly finished and conform to the dimensions shown on the drawings.

133. Castings shall be cleaned, and seams and other blemishes removed.

134. Drainage holes not less than three-fourths in. in diameter shall be drilled in places where water is likely to collect.

Play for Unfinished Bolts.

135. Unfinished bolts may have a play of $\frac{1}{16}$-in. in the bolt holes. Turned bolts must have the diameter of the shank at least $\frac{1}{16}$-in. larger than the diameter of the threaded portion, and must have a driving fit in the bolt hole.

Racks and Contact Surfaces.

136. The backs of racks and surfaces in contact shall be planed.

Grooves in Sheaves.

137. The grooves in circumference of sheaves carrying wire ropes shall be turned to a radius that will fit the rope. This is to be done after the sheave is completely assembled and permanently riveted up.

Tread Plates.

138. The top and bottom of the tread plates and surfaces in contact in rolling bridges shall be planed to fit. A full bearing must be made.

Gear Teeth, Etc.

139. The periphery and the ends of teeth which mesh with shrouded teeth shall be planed and the pitch line scribed thereon.

Finishing of Trunnions, Etc.

140. Journals and trunnions shall be turned with a fillet where the section changes. Journals shall have a collar at each end. Trunnions and journals eight inches in diameter and over shall have a hole one and one-half inches in diameter bored through on the longitudinal axis. Journals, trunnions, and bushings must be polished after being turned. The use of a cutter which trembles or chatters will not be allowed.

141. The joints between the caps and bases of journal and trunnion bearings shall be planed. The ends of the bases and surfaces in contact with the supports shall be planed. Bolt holes for holding the cap to the base and for holding the base to its support shall be drilled.

Grooves.

142. The grooves in the surface of trunnions or similar large bearings shall be machine cut. Chipping and filing will be allowed only for removing small inequalities. The grooves shall be smooth, especially the rounded corners.

Hubs.

143. Hubs of wheels, pulleys, couplings, etc., shall be bored to fit close on the shaft or axle. If the hub performs the function of a collar, the end next to the bearing shall be faced. Holes in hubs of toothed gear wheels shall be concentric with the pitch circle.

Cut Gears, Etc.

144. The periphery of gear wheels shall be turned. Gear wheels and racks which are a part of the train which actuates the moving span shall be cut. Other gears, except beveled gears and worm gearing, shall be machine molded, or cut.

145. If any molded gears are shrouded, chipping or other means shall be used at the junction of the shrouding and teeth to insure proper meshing.

Beveled Gears, Etc.

146. Beveled gears shall be cut. The cutting shall be done by a planer having a rectilinear motion to and from the apex of the cone. Rotating milling cutters shall not be used.

147. Threads on worms and the teeth of worm wheels shall be cut and fit accurately. Point contact shall be avoided.

148. Any two surfaces which slide, roll, or bear on each other shail be planed or turned to fit.

Assembling of Machinery.

149. Machinery parts shall be assembled on the supporting members in the shop, and shall be aligned and fitted, and holes in the supports drilled, with the members in correct relative position. The members shall be match marked both to the supports and to each other, and re-erected in the same relative position.

Holes for Sheaves for Vertical Lift Bridges.

150. The holes in the girders and columns for the bolts connecting the main sheave bearings to their supporting girders shall be drilled from the solid through cast-iron or steel templates on which the bearings were set and accurately lined when the holes in the bearing were bored. The bolt holes and the bolts shall be turned to the same diameter and the bolts driven to place without injury to them, the bearings, the girders, or the columns.

Testing of Trunnion Bearings.

151. Trunnions shall be turned to a diameter of 1/64-in. less than that of the bushing. Before shipping, the trunnions shall be placed in their bearings and given two full rotations. If any grinding or hard turning is found, it must be remedied. The tests shall be made in the presence of the Railroad Company's inspector.

Facing of Couplings.

152. Faces of flange and split muff couplings shall be planed to fit. The couplings shall be keyed to the shaft.

Keys, etc.

153. A special effort to secure good workmanship on keys and key-ways shall be made. Keys and key-ways must be machine planed or cut.

Coating of Surfaces.

154. Machined surfaces shall have a coating of white lead applied to them.

Guarantee of Machinery.

155. Machinery which is of the regular standard manufactured type, such as steam, gasoline, and electric motors, pumps, air compressors, etc., shall be guaranteed by the manufacturer as to efficiency, and shall be

subject to the approval of the Engineer. Motors shall be tested to prove that they fulfill the specified requirements and develop the desired speed, power, and torque.

Air Buffers.

156. The workmanship on air buffers shall be so accurately done that the weight of the cylinder and its attachments will be sustained by the confined air for a period of six minutes; at the end of this time, the piston may be in the position it occupies when the bridge is closed. The valves must be closed and the buffers so balanced that the whole is carried by the piston rod. (24).

UNIT STRESSES.

Normal and Excess Loads.

157. Machinery parts shall be designed for the normal loads used in determining the torque curves, using the unit stresses herein specified. For the excess torque specified for the prime mover, twice the normal unit stresses will be allowed. (181), (208), (211).

Braking.

158. If brakes act through the machinery, the unit stresses produced by braking shall not exceed by more than 50 per cent. those caused by the normal torque of the prime mover. (33), (159), (160), (161).

159. The unit stresses per square inch to be used for parts in which the effects of impact are taken care of by the use of low unit stresses, instead of increasing main stresses are (37):

STRESSES IN ONE DIRECTION.

Material	Tension Lbs.	Compression	Fixed Bearing	Shear
Machinery steel	9,500	$9{,}500-40\frac{l}{r}$	13,000	6,500
Forged structural steel	9,000	$9{,}000-39\frac{l}{r}$	12,500	6,400
Rolled structural steel	8,000	$8{,}000-35\frac{l}{r}$	12,000	6,000
Steel castings	7,000	$8{,}000-35\frac{l}{r}$	10,000	5,000
Phosphor-bronze	2,500	....	......	4,500
Cast-iron	1,500	8,000	......	3,000
Shear on keys	5,000	....	......	.....
Bearing on keys	9,000	....	......	.....

For rolled or forged nickel steel, increase unit stresses of corresponding structural steel by one-half.

Wire Rope.

160. Maximum unit tension in plow steel cables for counterweights shall be one-sixth of ultimate; for operating cables one-eighth. The maximum unit tension is equal to direct unit stress plus extreme fiber unit stress in the individual wire due to bending over sheave. (162), (163), (164).

Reversal of Stresses.

161. For stresses which are reversed at the rate of 10 or more times per minute, use one-half of the above unit stresses.

Bending of Wire Rope.

162. If wire rope is bent over a sheave, the bending stress and permissible load on the rope shall be calculated as follows:

Let P = the total pull or permissible load, in pounds, on the rope;
K = extreme unit fiber stress in greatest individual wire;
E = modulus of elasticity = 28,500,000;
a = cross-section area of rope, in square inches;
d = diameter of thickest wire, in inches;
D = diameter of sheaves to center of rope, in inches;
S = greatest unit tension allowable;
α = angle of helical wire with axis of strand;
β = angle of helical strand with axis of rope;
c = diameter of rope, in inches.

$$\text{Then } K = \frac{Ed \cos.^2 \alpha \cos.^2 \beta}{D} \quad \ldots\ldots (1)$$

$$P = a\left(S - \frac{Ed \cos.^2 \alpha \cos.^2 \beta}{D}\right) \quad \ldots\ldots (2)$$

For rope having six strands of nineteen equal wires each,

$$P = a\left(S - \frac{1\,800\,000\,c}{D}\right) \quad \ldots\ldots (3)$$

because $\cos.^2 \alpha \cos. \beta = 0.95$, $d = \frac{c}{15}$.

163. For haulage rope, six strands of seven wires each, take $d = \frac{c}{9}$.

164. If a rope is in contact with a sheave over a small arc, the actual radius of curvature may be greater than that of the sheave. (Fig. 1.)

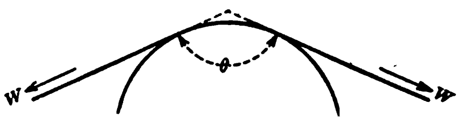


FIG. 1.

Let R = the actual radius of curvature;
θ = the angle between the directions of the rope;
W = pull on individual wire, equal to P divided by the number of wires if all wires are of equal diameter.

$$\text{Then } R = \frac{4\,d^2}{17\cos.\frac{\theta}{2}}\sqrt{\frac{E}{W}}$$

165. If R is greater than the radius of the sheave, $2R$ should be used in place of D in formulas (1), (2), and (3). The formula is only valid for θ between 130 and 180 degrees.

Strength of Gear Teeth.

166. The strength of cut gear teeth shall conform to the following formula, one tooth only taking pressure:

$$P = fpb\left(0.154 - \frac{0.912}{n}\right)\frac{600}{600 + v},$$

in which

$P =$ pressure on tooth, in pounds;
$f =$ permissible unit stress $=$ 17,000 lbs.;
$p =$ pitch, in inches;
$b =$ face of breadth of tooth, in inches;
$n =$ number of teeth in gear;
$v =$ velocity on pitch circle, in feet per minute.

167. The strength of machine molded teeth shall be calculated by the foregoing formula, taking $f = 15{,}000$ lbs.

168. The foregoing formula is for involute teeth having an angle of obliquity equal to 20 degrees.

Pressure on Rollers.

169. The pressure, in pounds per linear inch, on rollers at rest shall be for rolled and cast steel 600 d, where d equals diameter of roller, in inches.

UNIT STRESSES FOR BEARING ON ROTATING AND SLIDING SURFACES.

170. The maximum bearing values for rotating and sliding surfaces, in pounds per square inch; use diametral area for rotating surfaces:

For bearings on which the speed is 100 feet or less per minute and intermittent:

	Pounds Per Sq. In.
Trunnion bearings on bascule bridges; machinery or structural steel on phosphor-bronze	1,500
Wedges; cast steel on cast steel or structural steel	500
Screws which transmit motion on projected area of thread	200
For ordinary cases, parts moving at moderate speeds:	
Hardened steel on hardened steel	2,000
Hardened steed on bronze	1,500
Tool steel (not hardened) on bronze	900
Structural steed on bronze	600
Cast-iron on structural steel	400
On cross-head slides, speed not exceeding 600 ft. per minute	50

171. In order to prevent heating and seizing at higher speeds, the pressure on pivots or footstep bearings for vertical shafts and journals shall not exceed:

On pivots............................ $p = \dfrac{40{,}000}{n\,d}$ per sq. in.

On journals.......................... $p = \dfrac{300{,}000}{n\,d}$ per sq. in.

Where n = number of revolutions per minute;
d = diameter of journal or pivot, in inches;
p is taken in pounds.

172. For crank pins and similar joints with alternating motion, the limiting bearing values given in the above formula may be doubled.

173. Permissible pressure, in pounds per linear inch of roller in motion:

For cast-iron .... $p = 200\,d$
For steel castings........................... $p = 400\,d$
For machinery steel......................... $p = 500\,d$
For tool steel................................. $p = 800\,d$
For hardened tool steel..................... $p = 1{,}000\,d$

Where p = pressure per linear inch of roller;
and d = diameter of roller, in inches.

174. The foregoing values are for rollers and bearing surfaces of the same material; if rollers and bearing surfaces are of different materials, the lower value shall be used.

POWER EQUIPMENT.

General Requirements.

175. The kind of motor best adapted to any particular case depends upon local conditions, and should be left to the judgment of the Engineer.

Mechanical Power.

176. If the bridge is operated by mechanical power, the motor shall be of ample capacity to move the bridge at the required speed. No matter what mechanical power is used, all bridges shall also be provided with hand-power operating machinery.

Friction Brakes.

177. Friction brakes, to be operated by hand or foot, shall be provided where the motor is located in the operator's house. They shall have sufficient capacity to stop or hold the moving span in any position under all conditions.

Operator's House.

178. If mechanical power of any kind is to be used for operating a movable bridge, a suitable house shall be provided for the operator. The house shall be of such dimensions as required for the purpose for

which it is to be used. It shall be placed in a position where the operator can observe the signals and see the approaching vessels and trains, and have enough windows of sufficient size, so that his view will not be obstructed. If the operator's house is above or below the floor of the bridge, suitable steel or iron stairs with railings shall be provided to lead from the floor of the bridge to the floor of the operating house. The house shall be of fireproof construction, consisting of a steel frame, steel floor joists, and a fireproof floor. If the house contains motors and machinery, the floor shall preferably consist of steel plates, but if the motors are located elsewhere, the floor between the joists may be of concrete construction. The sides and roof shall be of metal, concrete, or any other non-combustible material. The hand rail for stairways and other places shall be made of 1½-in. gas pipe.

Heating of Operator's House.

179. Whenever climatic conditions require it, provision shall be made for heating the operator's house. If steam power is used, the house shall be heated by a steam coil or radiator fed from the boiler. If electric power is used, the heat may be supplied by electricity. If gasoline is used, or any other power which cannot be utilized for heating, a coal, wood, petroleum, or gas stove, as directed by the Engineer, shall be provided.

Whistle.

180. A whistle having a bell 3 in. in diameter and 10 in. long shall be installed complete. If operated by air, the compressor and air tank shall conform to the following specifications: The compressor shall be motor-driven, the motor and compressor being on one frame, and geared. All working parts shall be completely enclosed and self-lubricating. The compressor shall have a piston displacement of from 25 to 30 cu. ft. per minute when working against a tank pressure of 90 lbs. per sq. in. The compressor shall be provided with strainer, and automatic governor and switch, in order that the compressor may automatically start and stop at any predetermined tank pressure. The air receiving tank shall be 36 in. by 8 ft. or of equal capacity. The tank shall be galvanized, and good for a working pressure of 100 lbs. per sq. in. It shall be provided with pressure gage and pigtail, pop-valve, and drain cock, and have standard flanges bushed for 1½-in. pipe. Contractor shall furnish all pipe, pipe fittings, and valves; all to withstand a working pressure of 100 lbs. per sq. in.

Greatest Torque.

181. A prime mover shall be capable of exerting twice the greatest torque shown on the torque curves for the normal loads. The rating of a prime mover shall be the horse-power determined by the brake test. (157).

STEAM POWER.

Steam Engine.

182. If a steam engine is used, it shall consist of a double-cylinder, reversing engine, the mean piston speed of which shall not exceed 400 ft. per minute; it shall develop the desired power and speed with a steam pressure of 50 lbs. per sq. in. The engine shall be connected to the operating machinery by an approved friction clutch, arranged so that the moving and locking machinery can be operated alternately or stopped without stopping the engine.

Steam Separator.

183. In the steam supply pipe, and close to the steam chest, shall be placed a steam separator. This separator, under test with quality of steam as low as 66 per cent., shall show an average efficiency of 85 per cent. in five tests.

Boilers.

184. The steam shall be generated by one or two upright, tubular boilers, each of which shall have twice the capacity of the engine. The boilers shall be designed for a steam pressure of 150 lbs. per sq. in., and adapted to the kind of fuel specified by the Engineer; they shall be of open-hearth steel in accordance with the specifications for boiler plates appended hereto. They shall be encased in asbestos, covered with Russia iron.

185. Boilers shall also be in accordance with the specifications of the Mechanical Department of the Railway Company and conform to the civil laws.

Flues of Boilers.

186. Vertical boilers shall have submerged flues at the top.

Horse-Power of Boilers.

187. The total horse-power of the boilers shall be twice that of the engine, and shall be computed by the following rule: Calculate the inside area of the tubes, area of tube sheet next to the fire, and sides of the fire-box where this is in contact with the fire. Take the sum of these areas in square feet and divide by 15. The intention is to allow 15 square feet of heating surface per horse-power. At least one-half square foot of grate surface shall be provided per horse-power.

Equipment of Engine Room.

188. The engine-room shall be provided with a steel water tank of sufficient capacity; a duplex steam feed-pump; and an injector for each boiler, with necessary pipes and connections for feeding boilers separately or together; steam water-lifters with necessary strainers, flexible hose, and piping to lift the water from the river into the tank; a coal hoist and a steel coal bin of sufficient capacity, The engine-room shall be provided with suitable indicators for recording the positions of the moving span and locking apparatus.

INTERNAL COMBUSTION ENGINES.

Gasoline Motor, Etc.

189. If an internal combustion engine is used, one of the most substantial kind shall be selected, the maximum piston speed of which shall not exceed 600 ft. per minute. The engine shall have a reversing gear provided with approved friction clutches, to be operated by a hand wheel. The countershaft connecting the engine with the operating machinery shall be provided with disengaging couplings, arranged so that the moving and locking machinery can be operated alternately and in either direction without stopping the engine. Engines of 10 H.P. or more shall be started by compressed air. The fuel tank shall be located outside of the engine-house. The engine-room shall be provided with indicators for recording the positions of the moving span and locking apparatus.

Engine Cooling.

190. For bridges which are to be opened at intervals of fifteen minutes or less, and about four or more times per hour, the engine shall be water cooled. For longer intervals, the engine may be air cooled; for this purpose the outside cylinder shall have deep flanges about which a forced circulation of air is maintained by a fan.

Ignition.

191. The ignition shall be of the jump-spark kind in which the secondary coil is made up on each spark plug as part of it, so that a low-voltage current, not over ten volts, will be sufficient.

Extra Parts.

192. Two extra igniters and two extra crank pin brasses shall be furnished.

ELECTRIC EQUIPMENT.

A. I. E. E. Rules.

193. The electric equipment shall conform to the Standardization Rules of the American Institute of Electrical Engineers, as adopted June 21, 1907, or subsequent revisions.

N. E. C.

194. The National Electric Code shall apply to the electric construction and installation, except as may be noted hereinafter.

Wires and Insulation.

195. The quality of the wires and insulation shall conform to the specifications of the Railway Signal Association, as revised and adopted October, 1911. (See Vol. 8 of the Proceedings, pp. 576 to 587.)

Tests.

196. Any motor under test shall develop the required horse-power and torque at the armature shaft. Characteristic curves showing the results of the test shall be furnished by the manufacturer.

197. Motors shall be tested for the following voltages: normal, one-half normal and $1\frac{1}{4}$ normal. Characteristic curves shall be furnished for each test.

198. Motors, generators, automatic circuit breakers, solenoids, brakes, and other electric mechanism shall be tested at the factory by the manufacturer in the presence of the Railway Company's inspector.

Openings in Motor Case.

199. If the motor is enclosed in a case, as mill motors are, small openings of sufficient size shall be provided in the case for the inspection, removal, and replacing of brushes.

Motor Gears, Etc.

200. One cast steel cut gear, bored and key-seated for attachment to the countershaft, shall be furnished with the motor. The gear and pinion shall be covered by a sheet steel or malleable iron split gear case, supported by the motor frame, and completely covering the gear and pinion. An opening with a hinged cover shall be provided in the gear case for inspection and oiling. The gear ratio shall be such that the full speed of the countershaft will not be more than 125 revolutions per minute. Motors of 10 H.P. or over shall have an r. p. m. not to exceed 800, other motors not to exceed 1,000.

Motor Pinions.

201. Motors shall have a forged steel cut pinion, out of one piece, keyed to the end of the armature shaft and secured by a locknut.

Spare Motor Parts.

202. For each size of motor furnished, the Contractor shall supply the following spare parts: One armature, one field coil, one pinion, one gear, and one set of brushes. These parts shall be finished and fitted in such a manner as to admit of being installed in their respective places without further fitting or adjustment.

Mounting Motors.

203. The motors shall be mounted in such a manner as to admit of easy access for inspection and repairs; they shall be supported securely by brackets or suitable foundations.

204. If the machinery and motors are on the moving span, they shall be capable of being satisfactorily operated in any position of the span.

Housing of Motors.

205. Motors must be housed in weatherproof metal housing. This housing must be large enough to allow the inspection and oiling of the motor. It must be readily removable so that access to the motor may be obtained. Metal in this housing shall not be less than No. 16, U. S. Standard gage; it shall be galvanized.

D. C. Motors.

206. Direct current motors and generators shall be of the railway series, or mill, interpole type, weather and moistureproof, with slotted

drum armature and form wound armature coils. They shall be of a standard commercial type in common use. The best annealed refined wrought-iron shall be used for cores.

Testing of Motors.

207. The rating of a direct-current motor is the horse-power output at the armature shaft, which gives a rise of temperature above the surrounding air (referred to a room temperature of 25 degrees C.) not exceeding 90 degrees C. at the commutator and 75 degrees C. at any other part after one hour's continuous run at its rated voltage, on a stand with the motor covers removed and with natural ventilation. The rise in temperature is to be determined by thermometer, but the resistance of no electric circuit in the motor shall increase more than 40 per cent. during the test.

Excess Motor Loads.

208. Direct current motors shall be capable of exerting continuously for four cycles twice the normal torques shown on the torque curves for the moving span and machinery. The temperature shall not exceed those specified in Par. 207. One cycle is an opening and closing of the bridge in a specified time (157), (227), (229).

A. C. Motors.

209. Alternating current motors shall be of the three phase, induction type, with slip rings, rotor wound, 25 or 60 cycles, and 220 or 440 voltage, unless otherwise specified, and weather and moistureproof. The resistance for varying the speed shall be in series with the rotor circuit, and be such as to affect evenly all three phases. Motors of 5 H.P. or less may be of the squirrel-cage type. The best, and annealed, refined wrought-iron shall be used for cores.

210. Alternating current motors shall show, in a run for heat test, the following maximum temperature rises above 25 degrees C. for the surrounding room; for continuous run under nominal load, 40 degrees C.; for two hours run under 25 per cent. overload and a one minute run under 50 per cent. overload, 55 degrees C.

211. Alternating current motors shall be of rugged construction. The sum of the starting torques of the motors shall be at least equal to twice the greatest torque shown by the torque curves for the bridge operating machinery. The pull-out torque shall be at least equal to 1¼ times the starting torque (157), (227), (229).

Controllers.

212. The controllers for motors shall be located in the operating house. The controllers shall be of the reversing drum type, or flat type, with magnetic blow-out, and shall be capable of varying and maintaining the speed of the motors throughout the entire range desired, without injurious sparking, and without shock due to sudden variation in speed. The controllers shall be capable of doing their work for the usual loads, and excess loads, that may come upon the motors, with a temperature rise not exceeding that specified for the motors.

Controller Steps.

213. The controller shall have a sufficient number of notches or steps, such that the minimum or maximum motor torque will not differ by more than 10 per cent. from the average torque required for uniform acceleration.

Number of Controllers, Etc.

214. One controller shall be furnished for the operation of main motors, one for rail lock motors, and one for bridge lock motor. These controllers shall be so designed that the operation of any motor can be cut out by pulling a switch on the switch-board, without affecting the operation of any of the other motors.

215. The controllers for the two main motors, if for direct current, shall be of the series-parallel type; or of the type in which the field is varied, as may be done for the interpole type of motor.

Control of Motors.

216. The control of motors shall be electrically interlocked with each other and with the signal system, and the bridge shall be controlled in such a way that the end locks cannot be released until the signals have gone to danger position and derails are set, or the bridge motor started until the end locks have actually been released. In closing the bridge, the control shall be such as to make it impossible for the operator to move the end locks until the bridge has been completely closed, or to set the signals at safety until the bridge has been closed and the end locks are in place.

Master Controller.

217. For currents too large for the usual type of controller, the motor circuits shall be made by contactors mounted on panels or frames. These contactors shall be operated by solenoids, which are controlled by a master controller.

Automatic Control.

218. For large structures, automatic control may be used, but this is too complicated to be covered by a specification. This should be taken up for special consideration with the Engineer.

Resistance.

219. Resistances shall be of the cast grid type, and of such capacity that the motor can be operated continuously at any point of the controller when developing normal torque, or for 15 minutes when developing excess torque, without sufficient rise in temperature of the resistance to cause deterioration of any part. The resistances shall be mounted so as to admit of free ventilation and be without injurious vibration (208), (211), (227).

Electric Brakes.

220. The main operating motors, rail lock motors, and bridge lock motors, shall be provided with approved post brakes which are held in set position by a spring with such force as to overcome not less than

50 per cent. of the maximum torque required. The friction surfaces are to be of materials not affected by moisture. The brakes are to be released by solenoids of ample power and heating capacity whenever the motors are taking current, and are to be automatically set whenever the current fails or is cut off from the motors. Moistureproof motors shall be provided with moistureproof solenoids. Brakes shall be provided with a foot-switch release for coasting purposes. Means shall be provided for mechanically releasing the brakes when the bridge is to be operated by hand or other equipment.

Emergency Brakes.

221. An additional emergency brake shall be provided and applied to the main operating machinery. This shall be released by solenoids or motors which shall hold the brake in release as long as the current is applied to the brake motor. Cutting off the current from the solenoids or motors, or any failure of current, will result in the instantaneous application of the brake. This brake will be normally set, but will be released by the operator before starting the bridge, and be held in release during the entire operation, unless an emergency condition arises requiring brake power in excess of that offered by the motor brakes, in which case it may be instantly applied by the operator. After the bridge has been closed and traffic has been resumed, this brake will again be applied. This portion of the equipment shall be so designed that it will not be injured if left in release indefinitely. Proper means shall be provided for mechanically releasing the brake when the bridge is to be operated by hand or emergency power equipment.

222. The emergency brake circuit shall be independent of the general interlocking system, and there shall be a mechanical interlocking device which will prevent the main leaf motors and the emergency brake being used one against the other.

223. The emergency brake switch shall be attached to the controller stand within easy reach of the operator, and proper labels shall be placed back of the switch handle to indicate "Set" and "Released" positions of the brake.

Automatic Cutoffs.

224. An automatic cutoff or short circuiting device shall be provided which will throw out the circuit breakers, and cut off the current from the operating motors, and set their brakes when the bridge is five degrees from its open position, and its closed position. Spring switches shall be provided, which if closed and held closed, will put the cutoffs out of service and thus enable the bridgetender to fully close or open the bridge.

225. The bridge lock motors and rail lock motors shall be stopped and the brakes set automatically at each end of the travel.

Sizes of Switches, Etc.

226. Switches shall be designed to carry not more than nine hundred (900) amperes per sq. in. of cross-section capacity. Any knife switch shall have not less than 100 amperes capacity.

227. Electrical parts, such as wires, switches, etc., shall be designed for the currents required for the motors when they exert the normal torques called for by the torque curves, on the supposition of continual performance through successive cycles of bridge operation. For excess torques and 15 minutes of operation, the temperature rise of the parts shall not exceed that for continual operation under normal torques. The excess torques shall be taken over successive cycles of bridge operation (208), (211).

228. Ground connections of ample area shall be provided. (See Fig. 4, Electric Review and Western Electrician, August 30, 1913.)

229. Circuit breakers and fuses shall be designed to act when the current through the motors is 110 per cent. the current required to make the motors exert twice the greatest normal torque (157), (181), (208), (211).

Fuses.

230. Enclosed fuses shall be used. A spare set of fuses, not less than six of any one kind, shall be furnished by the Contractor.

Kind and Minimum Wire.

231. No stranded wire smaller than No. 10 B. & S. gage shall be used. Circuits to all motors and all circuits running onto the moving span shall be of stranded wire throughout. Solid wire of not less than No. 12 B. & S. gage may be used for other circuits. No joints shall be made inside of a conduit.

Wires to Be Tagged.

232. Wires when installed shall be permanently tagged and numbered so that any wire can be traced from the switch-board to the motors and to the source of power.

Lightning Arrester.

233. The feeders shall be protected by a pole-switch fuse and lightning arrester, mounted on a non-combustible and non-absorbent insulating base.

Quick Break Switch and Switch-board.

234. A switch, of the quick break type, shall be provided for each supply wire. Each motor circuit and each light, signal, indicator, or other circuit, shall be provided with switches which are approved by the Railway Company's Engineer. The switches shall be mounted on an enameled slate panel switch-board (not less than 1½ in. thick, and free from metallic veins or flaws) in the operator's house. The switch-board shall be large enough to carry the meters, switches, cutouts, fuses, etc. Switches, cutouts, buttons, etc., shall be provided with a plate designating their use.

Automatic Circuit Breaker.

235. An automatic circuit breaker shall be placed on the switch-board in the operating motor circuit of the bridge. Each line to the

motor, each line to the electric brakes, and each lighting, signal, indicator, or other circuit, shall be protected by enclosed fuses.

236. Automatic circuit breakers, for main operating motors, shall be placed near the bottom of the switch-board with the other instruments above. Circuit breakers in circuits leading to motors of 10 H.P., or less, shall be placed at the top of the switch-board.

237. Any circuit whatsoever shall be protected by fuses, circuit breakers, or equivalent devices, which will insure the excessive current being cut off before any parts are damaged.

Lightning Arresters.

238. Lightning arresters shall be placed as near as practicable to the parts to be protected, and away from combustible material. A No. 4 B. & S. gage wire should be used for the connections; this wire should run in a straight line to a ground plate, and not be connected to any structural parts. To avoid inductive resistances, the wire should not run through a conduit. If a choke coil is used, it should be thoroughly insulated from the ground and other conductors.

Short-Circuiting.

239. The connections of parts in contact with track shall be such as to allow no short circuiting of track signals.

Prctection of Electric Contacts.

240. Electrical contacts shall be protected from the weather or accumulations of dirt. A spare set of all contacts and contact fingers shall be furnished by the Contractor.

Coils.

241. Coils shall be impregnated.

Solenoids, Etc.

242. Solenoids and electrically operated brakes shall be housed.

Indicators.

243. The Contractor shall provide and install electric light indicators for the purpose of showing the operator the various positions of the bridge, especially the fully open, entirely closed, nearly open, and nearly closed positions of the bridge, and fully closed and fully open positions of the rail lock and bridge locks.

Volt Meter, Etc.

244. A volt meter, ammeter and watt meter shall be provided on the switch-board.

Ground Detector.

245. The switch-board shall be furnished with one two-candlepower lamp for detecting ground, and a two-candlepower lamp for illumination at each ammeter and volt meter scale.

Lamps for Lighting.

246. In the operator's house shall be placed ten 16-candlepower lights, and additional lights about the machinery, and such other lights

as the Engineer may direct. For all lights in the house above ten in number, the Railway Company will pay the regular market price or furnish them to the Contractor.

247. Lights of 16-candlepower shall be placed outside at the head and foot of stairways or similar paths.

248. All lights in the house shall have tungsten filaments. Outside lights shall have weatherproof sockets.

Channel Lights.

249. The Contractor shall furnish warning and channel lights and signals, in accordance with the U. S. Government requirements, or other harbor requirements. The Railway Company will furnish a copy of the U. S. Government regulations.

Railway Signal System.

250. The Company will furnish and install the railway signal system, also the master lever and all necessary devices controlling the interlock between this signal system and the bridge as a whole. The Contractor shall furnish and install the necessary devices for interlocking the various parts of the bridge with each other and for connections to the Company's master lever.

251. Emergency switches shall be provided which will free the various motors from the interlocking in emergencies. These switches shall be mounted on the switch-board, and each switch covered by a separate sealed or locked glass case.

Phase Wires in Conduits.

252. To lessen inductive effects, the phase wires in alternating current circuits shall be placed close together in one conduit. Not more than three (3) circuits shall be placed in a conduit. A circuit in three-phase work means 3 wires.

253. Submarine cables, if needed, will be furnished and laid by the Railway Company.

Conduits, Etc.

254. Wires shall be placed in metal conduits wherever practicable. At points where stationary conduits join the conduits on the moving span, flexible metal conduits shall be used for bending action. The flexible conduits shall be connected by combination couplings to junction boxes, with slate terminal boards, at each end of flexible conduit. The conduits shall be sherardized or loricated on the inside and outside. Condulets, pull-out boxes, and ells shall be used; these shall be sherardized or loricated. To prevent the hardpulling of the wires through the conduits, bends shall be used sparingly. Built up junction boxes may be used where other fittings are not feasible. Conduits and boxes shall have suitably located drain holes. The combined area of the wires, including insulation, in any one conduit, shall not exceed 42 per cent. of the area of the conduit.

Minimum Thickness of Metal.

255. No metal covering for drum switches or similar parts or for junction boxes, etc., shall be less than No. 18, U. S. Standard gage. The following table shall govern the minimum thickness of metal conduits:

THICKNESS OF METAL CONDUITS.

Nominal Inside Diameter, in Inches.	Thickness in Inches.
½	0.109
¾	0.113
1	0.134
1¼	0.140
1½	0.145
2	0.154
2½	0.204
3	0.217
3½	0.226

SPECIFICATIONS FOR SPECIAL METALS USED FOR MACHINERY PARTS.

STEEL CASTINGS.

Qualities of Machinery—Steel Castings.

256. Steel for castings may be made by the open-hearth or crucible process.

Phosphorus	0.05 per cent. maximum
Sulphur	0.05 per cent. "

257. Minimum physical qualities, as determined on a standard test specimen of ½-in. in diameter and 2-in. gaged length.

Tensile strength, in lbs. per sq. in.	70,000
Elongation, percentage in 2 in.	18
Contraction of area, percentage	25

258. Castings shall be annealed.

259. A test to destruction may be substituted for the tensile test, in the case of small or unimportant castings, by selecting three castings from a lot. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow, annealed in the same furnace charge.

Flaws in Castings.

260. Castings shall be true to pattern and free from blemishes, flaws, or shrinkage cracks. When the bearing surface of any steel casting is finished, there shall be no blow holes visible exceeding one inch in any

direction, nor exceeding ½ sq. in. in area. The length of blow holes cut by any straight line laid in any direction shall never exceed one inch in any one foot.

Blow Holes in Gear Wheels.

261. No blow hole exceeding one-half the above dimensions and area will be allowed in any gear tooth, or in the rim at the root of the teeth.

Electric Welding.

262. The correction of defects in castings, by welding electrically, by thermit, or by similar processes, will not be allowed.

Testing of Large Castings.

263. Large castings shall be suspended and hammered all over. No cracks, flaws, defects, or weakness shall appear after such treatment.

264. A specimen (1 in. by ½-in.) shall bend, cold, around a diameter of 1 in., through an angle of 90 degrees, without fracture on the outside of the bent portion.

265. The number of standard test specimens shall depend upon the character and importance of the casting. A test piece shall be cut, cold, from a coupon to be molded and cast on some portion of one or more castings from each melt or blow, or from the sinkheads (in case heads of sufficient size are used). The coupon or sinkhead must receive the same treatment as the casting or castings, before the specimen is cut out, and before the coupon or sinkhead is removed from the casting.

266. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in phosphorus and sulphur, specified in paragraph 256, concerning chemical properties.

STEEL FORGINGS.

Qualities of Steel Forgings.

267. Steel forgings may be made by the open-hearth or crucible process.

Phosphorus	0.04 per cent. maximum
Sulphur	0.05 per cent. "

268. Minimum physical properties, as determined on a standard turned test specimen of ½-in. in diameter and 2-in. gaged length:

Tensile strength, in lbs. per sq. in.......	85,000 to 65,000
Elongation, percentage in 2 in...........	28

269. A specimen (1 in. by ½-in.) shall bend, cold, 180 degrees, around a diameter of ½-in., without fracture on the outside of the bent portion. The bending may be effected by pressure or by blows.

270. The number and location of the test specimens to be taken from a melt, blow or forging shall depend upon its character and importance,

and, therefore, must be regulated by individual cases. The test specimens shall be cut, cold, from the forging, or full sized prolongation of the same, parallel to the axis of the forging and half way between the center and the outside; the specimens shall be longitudinal, i. e., the length of the specimen shall correspond with the direction in which the metal is most drawn out or worked. When forgings have large ends or collars, the test specimens shall be taken from a prolongation of the same diameter or section as that of the forging back of the large end or collar. In the case of hollow shafting, either forged or bored, the specimen shall be taken within the finished section prolonged, halfway between the inner and outer surfaces of the wall of the forging.

271. Turnings from the tensile specimen, drillings from the bending specimen, or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether or not the steel is within the limits in chemical composition.

272. Forgings shall be free from cracks, flaws, seams, or other injurious imperfections, shall conform to the dimensions shown on the drawings furnished by the purchaser, and shall be made and finished in a workmanlike manner.

273. All forgings shall be annealed.

MACHINERY STEEL.

Qualities of Machinery Steel.

274. Machinery steel shall be made by the open-hearth or crucible process.

Phosphorus	0.05 per cent. maximum
Sulphur	0.05 per cent. "

275. Minimum physical properties, as determined on a standard turned test specimen of ½-in. in diameter and 2-in. gaged length:

Tensile strength, in lbs. per sq. in................	80,000
Elongation, percentage in 2 in....................	20

276. A specimen (1 in. by ½-in.) shall bend, cold, 180 degrees. around a diameter of 1½-in., without fracture on the outside of the bent portion. The bending tests may be made by pressure or by blows.

277. Turnings from the tensile test specimens or drillings from the small test ingot, if preferred by the inspector, shall be used to determine whether the melt is within the limits in chemical composition.

BOILER PLATES.

Qualities of Boiler Plate Steel.

278. The steel used for boilers and fireboxes shall be made by the open-hearth process.

Phosphorus	0.04 per cent. maximum
Sulphur	0.04 per cent. "

279. The physical properties required shall be as follows:

Tensile strength desired, in lbs. per sq. in....... 60,000

Elongation, minimum per cent, in 8 in. $= \dfrac{1,500,000}{\text{ultimate strength}}$

Character of fracture ....Silky

Cold bends, without fracture ....180 degrees flat

280. The ultimate strength shall come within 4,000 lbs. of that desired.

281. Chemical determinations of the percentages of carbon, phosphorus, sulphur, and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of each analysis shall be furnished to the Engineer or his inspector. A check analysis shall be made from the finished material, if called for by the purchaser, in which case an excess of 25 per cent. above required limits will be allowed.

282. Specimens for tensile and bending tests for plates shall be made by cutting coupons from the finished product, which shall have both faces rolled and both edges milled to the usual form of the standard test specimen, 1½ in. wide on a gaged length of at least 9 in., or with both edges parallel.

NICKEL STEEL FOR MACHINE PARTS.

Qualities of Nickel Steel.

283. Nickel steel shall be made by the open-hearth process.

	Plates, Shapes, and Bars. Per Cent.	Rivets. Per Cent.
Phosphorus shall not exceed	0.04	0.04
Sulphur " " "	0.05	0.04
Nickel not less than	3.00	3.25

284. The physical properties required shall be as follows:

	Plates, Shapes, Bars and Forgings. Pounds Per Square Inch. Minimum.	Rivets. Pounds Per Square Inch.
Tensile strength	80,000	60,000 to 70,000
Elastic limit	50,000	40,000 min.

Elongation, percentage in 8 in., for plates, shapes, bars and forgings, and also for rivets, $= \dfrac{1,600,000}{\text{ultimate strength}} =$ min. Elongation, percentage in 2 in., for forgings = 25 per cent.

285. Specimens cut from forgings (1 in. by ½ in.) shall bend, cold, 180 degrees, around a diameter of 1 in., without fracture on the outside of the bent portion.

286. Specimens cut from plates, shapes and bars shall bend, cold, 180 degrees, around a diameter of three times their thickness, without fracture on the outside of the best portion.

287. Each rivet rod shall bend 180 degrees, flat on itself, without fracture on the outside of the bent portion.

288. Rivet rods shall be tested as rolled.

289. The fracture of all tension tests shall show a fine, silky texture, of a uniform bluish-gray or dove color, free from black or brilliant specks, and shall show no signs of crystallization.

290. All nickel steel forgings shall be properly annealed.

291. Annealed eye bars and similar members, when full-sized pieces are tested, shall comply with the following requirements:

Minimum ultimate tensile strength, in lbs. per sq. in., 75,000.

Minimum elastic limit, in lbs. per sq. in., 45,000.

Minimum elongation in 10 ft., including fracture, 12 per cent.

The fracture shall be mostly silky, and free from crystals.

Full-sized pieces shall bend, cold, 180 degrees, around a diameter of twice their thickness, without fracture.

TOOL STEEL.

Qualities of Tool Steel.

292. This steel is usually used for parts which require hardening or oil tempering, such as pivots, friction rollers, ball bearings and springs.

293. Tool steel shall be made by the open-hearth or crucible process.

Carbon	1.00 per cent. minimum
Phosphorus	0.04 per cent. maximum
Sulphur	0.04 per cent. maximum
Manganese	0.50 per cent. maximum

PHOSPHOR-BRONZE.

Qualities of Phosphor-Bronze.

294. Special phosphor-bronze shall be used for high pressure and slow speed.

295. Phosphor-bronze shall be a copper-tin alloy; phosphorus not to exceed 1 per cent. Other alloys, up to one-half of 1 per cent., will be permitted, except that no sulphur will be allowed.

Compression:

Elastic limit, in lbs. per sq. in. .... 19,000 to 23,000

Permanent set, under 100,000 lbs., in inches 0.12 to 0.16

296. The compression is to be made on a cylinder having a height of one inch and an area of one square inch. The elastic limit is to be the load which gives a permanent set of 0.001 inch.

Tension:

The yield point, ultimate strength, and elongation in 2 in. are to be recorded. The tension specimen is to have a diameter of ½-in.

297. For every heat at least two tests shall be made. A chemical analysis shall be furnished.

BABBITT METAL.

Qualities of Babbitt Metal.

298. Babbitt metal composed of the following ingredients and of the following proportions has given satisfactory results:

Copper	3.6 per cent.
Tin	89.3 per cent.
Antimony	7.1 per cent.

VANADIUM CAST STEEL.

299. Vanadium cast steel shall contain at least 0.185 per cent. vanadium. It shall have the following approximate physical qualities:

Tensile strength	75,000 lbs. per sq. in.
Elastic limit (minimum)	45,000 lbs. per sq. in.
Elongation (minimum)	20 per cent. in 2 in.
Reduction of area (minimum)	30 per cent.

300. The remaining qualities shall conform to those of ordinary cast steel as set forth in these specifications, except that visible blow holes will not be allowed.

Purpose of the Specifications.

301. It is the purpose of these specifications to provide a first-class structure. They are intended as an aid in designing and fabrication. The subject of machine design and kindred subjects is so great and varied that no single work of this character can cover all points. As a further aid in securing a first-class structure, the following works will be considered authoritative, in the order named:

1. Unwin's "Machine Design," Part I, Ed. 1909.
   Unwin's "Machine Design," Part II, Ed. 1912.
2. "A Manual of Machine Design," etc., by Low & Bevis, 11th impression.
3. Reuleaux's "Constructor," translated by Suplee.
4. Kent's "Pocket Book," 8th Ed.

302. Machine parts shall be designed, if practicable, by the methods of applied mechanics, but such designs shall be viewed in the light of experience. It should be borne in mind that machine design is not based on the precise methods in vogue for stationary structures.

INDEX.

NOTES ON L. C. L. FREIGHT HOUSES.

By E. H. Lee,

Chief Engineer, Chicago & Western Indiana Railroad; President Western Society of Engineers; Member A. R. E. A., A. S. C. E.

ILLUSTRATIONS.

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2. Chart: Relation Between Length of House and Operating Costs.
3. Typical Cross-Section, Outbound House.
4. Typical Cross-Section, Inbound House.
5. Typical Cross-Section, Inbound and Outbound Houses.
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1. Investment per Car and Interest Charges per Ton, One and Two-Level Freight Houses.
2. Freight House Data (Size, Business and Cost).
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6. Average Trucking Distance.
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INTRODUCTION.

During the last three or four years the writer has been collecting the facts submitted in this paper, in order to verify, to his own satisfaction, at least, certain assumptions which were made, and which were the foundation upon which rested some of the principal features of plans for a development of terminals, both passenger and freight, which he was required to prepare in the course of his regular duties.

Terminal facilities are rapidly becoming the particular element of fixed investment for many railroad companies which most needs enlargement, and L.C.L. freight facilities are an important factor in terminal facilities as a whole. The great importance of determining the best means of increasing the capacity of large city freight houses, having due regard to economy in both investment and operation, is evident.

No claim is made to originality in what follows, neither is it intended that the conclusions reached shall be advanced dogmatically. If these notes draw out discussion, criticism and suggestion from members of the Association, they will have answered their purpose.

The writer wishes to express his thanks to Mr. F. E. Morrow and Mr. D. A. Tomlinson, and others among his assistants, for their aid in collecting the information herein presented, and in preparing

this paper. Acknowledgments are also due to a great many railroad officers and agents for information furnished, and for exceedingly courteous treatment in every case. Mr. R. C. Weller, of the New York Central Lines, who has collected a mass of information, similar to that herein, but for another purpose, very kindly made a considerable part available both as information and for purposes of comparison.

The package (L.C.L.) freight business of large cities is an important part of city freight traffic, in Chicago amounting approximately to 10 per cent. of the total tonnage and 25 per cent. of the total cars handled. In cities the proportion of L.C.L. to the total is much higher than when the entire freight traffic of the country is considered, the L.C.L. tonnage of the United States being but 4.3 per cent. of the total tonnage, and the L.C.L. cars 12.7 per cent. of the total. This ratio of package freight to the total traffic is naturally higher in cities than in the country as a whole, because it is derived largely from manufacturers and wholesale houses located in the cities. This class of traffic is also of greater importance than appears from its proportion to the total business, because it is high-class freight, carried at high rates, averaging from $40.00 to $50.00 per car, or from $6.00 to $8.00 per ton. Although the gross revenues thus derived are large, the cost of handling this class of business is very high, as terminal fixed charges and operating expenses, including charges absorbed, sometimes amount to $2.00 or more per ton ($1.50 fixed charges, 50 cents operation). Such costs at each end of the shipment consume a large part of the rate received. Any means of reducing interest charges or operating expenses, or of giving better service to the public, should be given careful consideration.

The need of centrally located, accessible freight houses, for both railroads and shippers, is apparent to even the casual observer. The cost per ton-mile of teaming is many times the ton-mile freight rate, for example in the downtown districts of Chicago it is estimated to be 50 cents, exclusive of the cost of loading and unloading. A well-located, accessible freight house is a valuable asset to a railroad, and is of great importance to shippers and to the city as a whole, because a city's prosperity is closely related to its commerce. Other conditions being equal, the city having the best railroad facilities will grow most rapidly, and the railroad having the most convenient freight houses will get the most business.

The L.C.L. business is at present growing at the rate of about 5 per cent. a year. It therefore doubles every fifteen (15) years. This growth, although it increases gross earnings, in many cases causes great congestion and higher operating costs. In many cities the need for an enlargement of facilities is daily becoming more imperative and the cost greater, as ground values are also rising.

The usual freight-house layout is simple; a long, low, narrow building with a driveway on one side, and with from one to eight or

more tracks on the other. Inbound houses are wider and served by fewer tracks than outbound houses. A public street is often used for the driveway, but when this is done the street is usually widened from 10 ft. to 30 ft. that it may better accommodate standing teams. For small houses, and in locations where land is cheap, this is undoubtedly the most economical arrangement, but where land is worth from $5.00 to $20.00 or more per sq. ft., and where a house must be 800, 1,200 or even 1,800 ft. long to secure the necessary car capacity, the investment becomes increasingly heavy and the cost of operation high. Furthermore, when street and railroad grades are separated, the inclines between driveways and streets consume much valuable space and impose an added burden on teams and shippers.

In most cities a teamster drives up to the nearest door at an outbound house, and unloads his freight. The packages are then sorted and trucked to the proper car. As the packages in one drayload usually go to several different cars, the amount of trucking is great, while the clerical expense of receiving freight is minimized. Vice-versa, in an inbound house (in many cases), packages for each consignee are assembled from the different cars into one particular section and the teamster receives them there. Sometimes, however, freight is unloaded into the most convenient section, and the packages for one consignee are assembled from one or more sections for the teamster at the most convenient door. Thus, where each load of freight must be distributed from one door to several cars, or assembled from several different cars to one particular section, a large amount of trucking is necessary, and, of course, the longer the house the greater the trucking distance and the higher the cost of operation.

At some points, Cincinnati being an example, the teamster delivers each outbound package at its proper door, i. e., freight for Louisville is unloaded opposite the Louisville car, and freight for Pittsburgh opposite the Pittsburgh car. Conversely, all the inbound freight in a car is unloaded onto the platform directly in front of that car, and the teamster must stop at each section in which he may have freight. Although this method cuts the trucking costs to a minimum, it greatly increases the costs of receiving and delivery, delays the teamsters, and even if teamsters are thoroughly familiar with the freight house, causes confusion, street or driveway congestion, and loss of time. In St. Louis the Shippers' Association recently protested against this method and the "One Dump" system was installed.

The business in city freight houses may roughly be divided into two classes, first, that originating or terminating in the city itself; second, transfer business, either between different roads or between different divisions of the same road. This transfer business is largely handled at the downtown freight houses. As the normal city outbound freight business is usually light in the morning hours, 50 per cent. being received after 3 o'clock in the afternoon, the transfer business

can often be efficiently handled in these houses, and without entailing increased facilities, because a more uniform distribution of work is obtained by handling transfer freight during the morning, and a higher loading per car and more "set out" cars are obtained by consolidating the transfer and city business. Many large roads, however, whose business is of sufficient volume to permit duplicate schedule loading, handle the transfer freight at transfer stations at break-up yards, near the outskirts of the city. This method leaves the expensive downtown terminals free for strictly city business, while the transfer business is handled at points where fixed charges are low. When the business of a road is sufficient to justify this separation it is undoubtedly advisable.

The high interest charges on downtown freight terminals may be illustrated by an inbound house in Chicago. It is 1,000 ft. long and 50 ft. wide, with a 40-ft. driveway on one side and two tracks on the other, occupying a total area of 1,000 ft. by 120 ft.=120,000 sq. ft. The land is valued at about $16.00 per sq. ft. The total land investment then is $16 × 120,000 = $1,920,000, exclusive of area occupied by leads. At 5 per cent. the interest charges are $96,000 per annum. The business handled is 50 cars per day or 15,000 cars per annum. The interest charges per car, then, are $6.40, or at six tons per car, $1.07 per ton. Adding to this the operating cost of 48 cents a ton, the total cost is $1.55. This is an actual example, and there are some thirty freight houses in Chicago alone whose charges may be considered somewhat similar.

For purposes of comparison the operating costs of a freight house may be divided thus:

Receiving;
Trucking;
Stowing;
Delivery;
$\left.\begin{array}{l}\text{Supervision}\\\text{Miscellaneous}\end{array}\right\}$ Overhead.

"receiving" including the checkers and callers; "trucking" the truckers, "stowing" the stowers; "delivery" the delivery clerks and their helpers; "supervision" the foreman and his assistants, and "miscellaneous" any messengers, coopers, car sweepers, etc. The proportion of each item to the total and the total itself varies, of course, with the character of business handled, the efficiency and method of operation in each house, and the wages paid. Table 3 gives these itemized costs for several houses.

Further, these items vary with the work necessary to handle each ton; that is, with the size and length of the house; the longer the house, the greater the average trucking distance and the higher the cost of operation. If to double the capacity of a given house, its length be doubled, then the trucking distance will also be doubled. This would not be true if two duplicate sets of cars were placed, one at each end

of the house, but this is rarely done, for it is better to have "set out" cars for as many points as possible rather than several peddler cars, or cars whose contents must be rehandled at a transfer station before reaching their destination. Theoretically the amount of trucking would increase in direct proportion to the length of the house. This is borne out by experience, as shown in Table 6, where the actual trucking distances (average) of several freight houses of various lengths, as determined by observations, are given. Fig. 6 shows this graphically. The line as plotted agrees closely with the observations, and shows that the amount of trucking varies directly with the length of the house; the average trucking distance being approximately 53 per cent. of the length of the house. The lengths and the costs of operation of 58 freight houses are given in Table 2. These show that the cost of operation increases with the length of the house. Fig. 2 shows this fact graphically, the operating costs given in Table 2 being plotted against the length of the house. A considerable variation is found in houses of the same length, largely due, as stated above, to differences in the character of the business, the efficiency and method of operation, and the wages paid. The normal line as plotted is believed to represent closely the average cost of operation for any length of house. It would not be exactly correct unless the conditions at all the houses were similar, but it is thought to be reasonably accurate under average conditions. This indicates an increase in cost of 1 cent per ton for every 35 ft. increase in length. The increase in the cost of operation, due to increasing the length of any given house, would probably be greater rather than smaller than the amount indicated by the normal line, although the costs of operation of outbound houses tend to increase more rapidly with the length than do those of inbound houses. It is clearly evident that any increase in the length of a house, although giving a greater car capacity, increases the cost of handling, not only of the additional business obtained, but of the entire business.

As the business district and population of a city expand railroad terminals become more valuable, and the costs of additional land and the freight facilities thereon constantly increase. Nevertheless as a city grows the freight traffic grows, present facilities become congested and inadequate and the need for more accessible and enlarged facilities becomes constantly more pressing.

Any freight house of the usual one-story type which handles adequately the business offered, has four kinds of facilities and these of sufficient capacity and proper proportions, viz.,

(1) Car standing capacity, including suitable lead or approach tracks.
(2) Platform area.
(3) Platform frontage for teams.
(4) Team driveways.

Table 4 gives these facilities of several existing houses, and their relation to each other. For instance, in outbound houses the platform area varies from 213 sq. ft. to 570 sq. ft. per car standing room, the average being 247 sq. ft.; the team frontage per car standing room varies from 4.6 ft. to 19.2 ft., the average being 10.2 ft.; the width of driveways varies from the street only to a 35-ft. private driveway. In most cases where the volume of business has reached, or is approaching the capacity of the house (and this is especially true in outbound houses), the particular facility which first feels the pinch of congestion, is car-standing capacity. This can be increased by the addition of more tracks against the house, although this decreases the team frontage per car, increases the cost of "spotting cars" and in inbound houses causes confusion between gangs of men working in different cars in the same "run"; or by adding to the length of the house and its present tracks, which also increases the cost of operation; by handling the transfer business at outlying points, thus relieving the terminals of all except strictly city business; by a more rapid handling of the business; by the use of trap cars, or by "double-decking," that is, by placing cars on each side of the house on one level, and driveways on each side on another. Either of the first two methods increases the investment in land and also (slightly) in improvements. Summarizing, increased car capacity may be obtained:

(1) By the purchase of additional land.
(2) By handling L.C.L. transfer at outlying points, relieving the terminals of all except strictly city business.
(3) By the more rapid handling of freight through the house.
(4) By the use of trap cars loaded on team tracks, later transferring the contents into schedule cars, obtaining a high tonnage from a small area of valuable property.
(5) By "double-decking," obtaining a greater car capacity from present ground holdings.

In small houses (200 or 300 ft. long) the first method of enlargement is probably the best, i. e., to double the capacity of a house by doubling its length. In the case of an outbound house, the addition of more tracks against the house may increase the capacity at low cost. With inbound houses, however, it is often undesirable to add more tracks. In houses over four or five hundred feet in length, an increase in length adds greatly to the costs of operation, and when more than four or five tracks are placed alongside a house, the cost of "spotting" cars and handling freight through them becomes high. In that case a duplicate house may be built. This is often done for inbound business, and offers no serious operating difficulties, but for outbound business would probably lead to many complications. This,

of course, doubles the facilities, but does nothing to reduce interest charges or operating expenses. Furthermore, the cost of additional land and expensive buildings thereon may be prohibitive, or the holdings of other roads may make this solution impossible. A point sometimes lost sight of is that each additional purchase of land for railroad purposes removes the potential commercial freight producing power of such area. Railroad holdings in the business district of a city may be so large as to tend to hamper its growth, and public sentiment against such additions may sometimes be strong. The need for keeping streets open, and for separating grades often makes difficult an efficient development of additional property. Thus in large cities where one-story freight houses grow so long as to be unwieldy, and where the acquirement of additional ground is expensive and difficult, if not impossible, it is evident that some other means for enlarging and improving freight terminals should be sought.

One method of relieving congestion at the cramped downtown terminals is to handle all or a large part of the L.C.L. transfer business at transfer stations located at the break-up yards. This increases the capacity of the terminals for strictly city business, although in some cases not in proportion to the amount of transfer tonnage taken elsewhere, and decreases the fixed charges on transfer business, in some cases as much as 95 per cent. However, it forces a duplicate loading of cars; one set of cars at the downtown houses and another set (for the same points) at the transfer station, and leaves the city freight house with an unbalanced peak of business in the afternoon. Where the business is small this double loading should be avoided, but if there is a sufficient volume of traffic, it offers a logical and simple means of decreasing congestion, or increasing capacity. Many large roads are now doing this, but are finding it insufficient, as the increased capacity is soon taken up by the growth of traffic. The city business is growing so rapidly that additional capacity is necessary even for it alone, and that capacity must be provided where land values are high and restrictions severe.

More rapid handling of freight through an inbound house would greatly increase its capacity; that is, the house could handle twice the business if the storage time before delivery could be cut in half. Or in an outbound house, if a more even flow of business during the day could be obtained, it might be possible to load two or three different "set ups" of cars daily, thus immediately doubling or trebling the capacity of the house. This, however, would involve a radical change in business methods on the part of shippers. It might cause a 24-hour delay in shipping orders, and, therefore, probably cannot be obtained without the co-operation of shippers. A substantial improvement would be possible, however, if shippers realized that larger morning deliveries to the railroad would result in decreasing congestion, thus decreasing the time necessary for cartage delivery, a benefit for both sides.

It is often possible to obtain a daily movement of cars 15 per cent. or 20 per cent. greater than the standing capacity of the house. by switching out loaded cars for points whose business requires two or more cars daily, but no great increase in capacity is thus obtainable. In most outbound houses the time required to place freight in its proper car after receipt from dray or truck is short. More rapid handling through the house by motor truck (or other means) has little effect on the capacity, and is justified only when it results in a saving in the cost of operation. In large houses, that is, houses over 800 ft. long, motor trucks have proven economical, in some cases cutting the trucking cost as much as 40 per cent., because one motor truck and driver can handle a greater tonnage than one man with a hand truck. Motor trucks are most efficient when used as power for hauling loaded trucks as trailers to be dropped opposite the proper car. This method secures the maximum tonnage and mileage from the motor truck, by reducing the loading and unloading time to a minimum, and it enables a motor truck and two men to handle 60 to 80 tons per day, whereas two men with hand trucks handle only 20 to 30 tons per day. In one case a motor truck with one man is reported as handling 60 tons per day. Although the cost of operation may be reduced as stated, yet little or no effect in increasing the capacity of a given house or piece of ground is secured.

From the foregoing it is evident that the need of increased facilities is often urgent; that further spreading out, both in first cost and in operation, is expensive and may be prohibitive; that even when houses are operated efficiently, to handle city business exclusively, the fixed and operating charges may be very high and that, therefore, some means of *increasing capacity and decreasing fixed charges and operating expenses* should be sought.

One method of securing a high tonnage from a small area of downtown property is that which has been in use in Minneapolis and St. Paul for several years, where some roads provide no outbound houses, but use team tracks instead.

Outbound freight is loaded indiscriminately into large box cars ("Jumbo" cars) at team tracks; the cars are pulled several times a day and taken to outlying transfer stations where the freight is transferred into schedule cars, the contents of "Jumbo" cars from several points being consolidated, thereby obtaining a high tonnage per car and very low interest charges, but adding the cost of loading the "Jumbo" cars (12 to 15 cents per ton) and some switching costs. This method, however, delays all freight received late in the afternoon until the following day. Where the freight from several scattered houses can be consolidated in this manner, and a heavier loading per car and less interest charges per ton obtained, this method appears simple and feasible, but in a highly competitive business it could not be advantageously used by any one road, unless also adopted by its competitors, owing to the delay of freight. As this delay would not permit many present over-

night deliveries, it can only be used to advantage where local conditions warrant.

Manufacturers have found it desirable to build factories of several stories instead of spreading one-story buildings over a much larger area, thus obtaining a more efficient use of ground and more efficient operation, by centralizing the plant. Similarly, by double-decking a freight house, with the tracks and driveways on different levels, but over the same ground area, it would seem that a railroad might obtain like results. For example Figs. 3, 4 and 5 show typical one-story freight houses and two-story developments for the same ground areas. These show that double-decking increases the car-standing capacity of a given piece of ground from 60 per cent. to 133 per cent.

A comparison of the relative facilities of these one and two-level developments is given in Table 7. This shows that double-decking maintains about the same relations between the different facilities that exist in the one-story houses, for not only is the car capacity increased, but the driveway frontage and area, and platform area as well.

Where land is cheap it is economical to use a larger ground area and less expensive improvements. But as land increases in value it becomes more economical to use less money for ground and more for improvements; that is, an increase in the money spent in improvements accomplishes a proportionately greater decrease in the amount of money necessary for land. Double-decking does this, and it also eliminates grade crossings, with the consequent delays to teams and the danger of accidents, due to switching. Moreover when streets are carried over tracks on viaducts or beneath them in subways, double-decking avoids the need for long, expensive inclines, between driveways and streets, which occupy space and tend to make a freight house inaccessible.

As, in such a house, freight must be handled between two levels, the cost of operation in some items is increased; but because the freight house is shorter and more compact, the operating cost in other items, especially the trucking, is reduced, often more than enough to offset the increase. Thus a two level house:

(1) Diminishes the investment in land.
(2) Adds to the cost of the improvement.
(3) Is especially feasible on sidehill locations or where grades are separated.
(4) Saves the space sometimes used for inclines between streets and driveways.
(5) Improves the street system, making the freight house more accessible.
(6) Decreases the operating cost, by shortening the trucking distance and by centralizing the operating force.
(7) Adds to the operating costs the item of elevating or dropping freight.

Taking these up in order:

The fact that double-decking will decrease the investment in land is apparent, for instead of having tracks on one side of a platform and a driveway on the other, tracks and driveways will be located on each side. A higher car capacity will, therefore, at once be obtained, while the driveway frontage per car will remain about the same. Figs. 3, 4 and 5 show cross-sections of typical one-story houses, and possible two-level developments of the same areas. The gain is obvious. Further, the diagrams show how readily a second level may often be adjusted to existing viaducts, thus saving long detours by teams, and long, space-taking inclines between streets and driveways.

In one terminal in Chicago where there are ten freight houses, handling over 700 cars a day, an average of 2,000 sq. ft. of ground is used per car standing room. There is much interference between teams and switch engines, and the approaches to some of the houses are long and circuitous. In a proposed two-level development of the same area it was found that only 1,300 sq. ft. would be necessary per car, a saving of 33 per cent. in area per car as compared with present conditions, making possible an increase in the capacity of present holdings of 50 per cent. In this plan grades are separated, interference between teams and engines is prevented, and all houses become more accessible. The cost of the present one-story improvements was about $1.00 per sq. ft. The estimated cost of the proposed development was $4.00 per sq ft. The cost of the present improvements is typical of freight houses in all large cities, and the estimate of the cost of the two-level development is believed to be liberal.

In many cases where space is used for inclines between streets and the driveways of single-level freight houses, an excellent double-deck development may be designed that will increase the capacity as much as 150 per cent. over a single-story development. Often, also, double-deck developments may be designed to use as little as 1,000 sq. ft. per car standing room. This means an increased efficiency of from 60 per cent. to 100 per cent. or even 150 per cent. for a given piece of land and a corresponding decrease in the fixed charges of from 20 per cent. to 50 per cent. or possibly more.

If 2,000 sq. ft. per car and $1.00 per sq. ft. for improvements be assumed as unit values for one-level houses, and 1,300 sq. ft. per car and $4.00 per sq. ft. for improvements for two-level houses, then curves may be plotted showing the total investment per car for different ground values, for one and two-level developments. Such a chart is shown in Fig. 1, the upper line showing the investment per car in one-level houses, the middle line the investment per car in two-level houses, using 1,300 sq. ft. per car, and the lower line in two-level houses using 1,000 sq. ft. per car. Thus when land is worth less than $4.50 per sq ft., a one-level house is the more economical, but when land is worth more than that a two-level house shows a saving; at $10.00 per sq. ft. a

saving of $3,800 per car standing room or 17 per cent.; at $15.00 per sq. ft. $6,300 per car or 20 per cent., and at $20.00 per sq. ft. $10,800 per car or 26 per cent.; thus the higher the land value the more economical a two-level development becomes. If a two-level development, using only 1,000 sq. ft. per car can be designed, the saving is even more

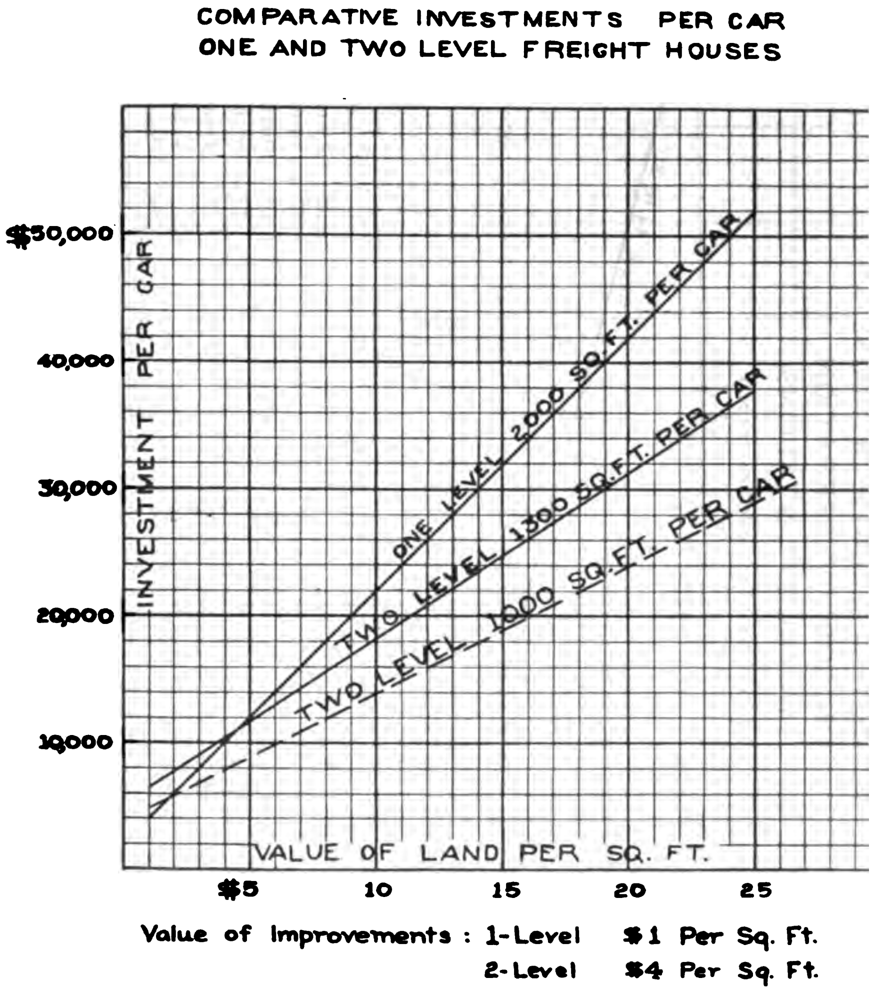


Fig. 1.

marked; at $10.00 per sq. ft., $8,000 saving per car, or 36 per cent.; at $15.00 per sq. ft., $13,000 per car, or 41 per cent., at $20.00 per sq. ft., $18,000 per car, or 43 per cent. In any case, values to fit local conditions may be assumed and graphs drawn.

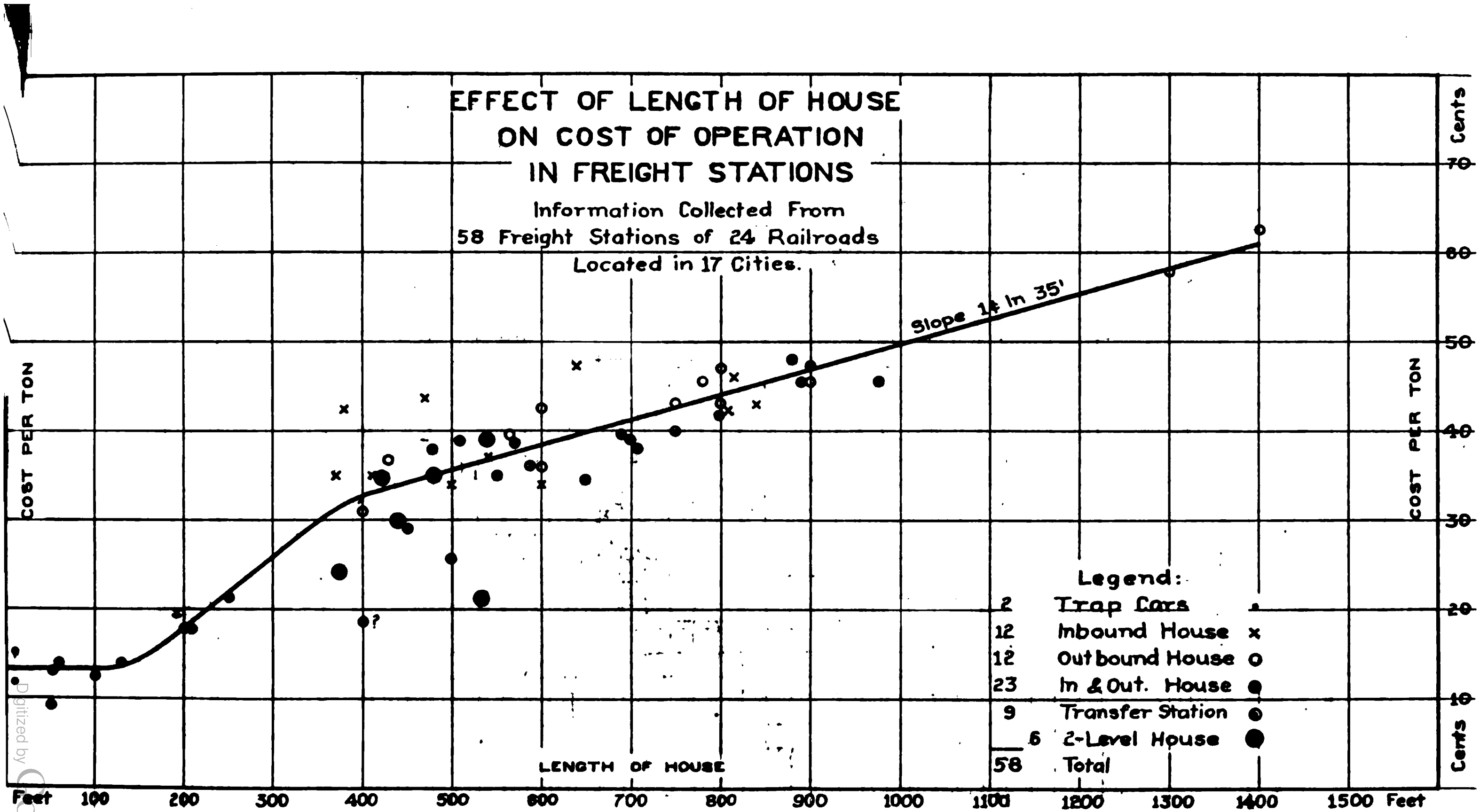


FIG. 2.

A considerable variation in the costs of operation is found in houses of the same length, due to differences in the method and efficiency of operation, the character of the freight, and the wages paid. A steady upward trend is evident, however, and the normal line as plotted is believed to be closely correct for average conditions.

The more the investment per car is reduced, the smaller become the fixed charges per ton of freight handled, and the greater the gain to the railroad company. Therefore, with the assumed values where land costs more than $4.50 per sq. ft., a double-deck freight house is less expensive than a single level; in other words an increase in the cost of the improvement produces a greater decrease in the cost of ground. Where enlargements to present facilities are needed, double-decking is sometimes the economical and logical method, and may be the only practicable solution.

By completely separating streets and tracks, and by removing sags and humps now present in street grades, a street system may sometimes be improved to the mutual advantage of city and railroad. Every such improvement in the street system is an advantage to the city, and also an advantage to the railroad. It makes the freight house more accessible, a direct asset to the railroad.

The typical cross-sections shown in Figs. 3, 4 and 5 (already referred to), show an increased capacity of from 60 per cent. to 130 per cent. possible in double-decking. In other words, a given car capacity may be obtained in from 40 per cent. to 60 per cent. less length in a double-deck than in a single-deck house. This would obviously result in a saving in trucking and in an increased efficiency in operation due to centralizing the working force. Referring again to Fig. 2, the costs of operation of 58 houses show that starting at 32.7 cents per ton, at a length of house of 400 ft., the average cost of operation increases about 1 cent for every 35 ft. increase of length. Conversely, decrease the length of the house 35 ft. and the cost of operation is decreased by 1 cent. per ton. For instance, if a capacity of 100 cars is desired, with four tracks against a platform, a one-story house would have to be 1,000 ft. long. A double-deck house with four tracks on each side of a platform would only have to be 500 ft. long. The saving in length would be 500 ft. and in operating costs under the assumption made would be $\frac{500}{35} = 14.3$ cents per ton.

But this saving is not all clear gain, for in a double-deck house some means must be provided for handling freight between the two levels, and this adds slightly to the cost of operation, and unless flexible, reliable, cheap, and efficient, would form a serious objection to this type of house. Freight can be transferred between two levels in several ways, viz:

(1) By telphers (overhead cranes).
(2) By gravity (chutes).
(3) By mechanical conveyors (moving belts or platforms).
(4) By elevators.

Where telphers are used the trucks are picked up by overhead traveling cranes, and lifted or lowered through hatchways. In one house

where telphers were installed it was found that this caused extra handling of all freight, as the telpher buggies had to be placed directly beneath the telpher runway, for the telpher covers a line and not an area. Hand trucks were therefore used to a large extent between dray and telpher buggy, and telpher buggy and car. The telpher could handle only one buggy load at one time, the breakage of freight was heavy, and the cost of power was relatively great, as the load could not be counterbalanced. The telphers were unreliable, breaking down frequently, to the demoralization of the whole working force. The system was unsatisfactory and the house has been remodeled and elevators installed. It may safely be stated that while telphers are useful in special cases they are not suited to ordinary L.C.L. freight-house use, for they lack flexibility, are unreliable and more or less unsafe, and they are very expensive, both in first cost and in operation and maintenance.

The second method, namely, the use of gravity, which is feasible when the cars are below the driveways in an outbound house, or above them in an inbound, would seem ideal, as gravity is free. A close study of operating conditions and methods, however, shows many defects. Packages must be unloaded from dray onto truck, trucked to the chute, unloaded into it, reloaded into another truck at the other end, and trucked to the proper car. The many rehandlings are expensive, costing much more than the expense required to handle freight by elevator. Moreover, a chute is limited in capacity, cannot handle packages of any great size or weight, or of odd shapes, damages fragile goods and is apt to cause congestion on the platforms around it.

Mechanical conveyors, inclined or perpendicular, would seem to be an efficient means of hoisting freight, but they are open to the same objections as chutes, namely, the necessity of extra handling, inflexibility, damage to freight, and congestion on the platforms.

In the factories or warehouses, where there is a steady flow of articles of uniform size and weight from one fixed point to another, chutes and mechanical conveyors between different levels, have proven very efficient, but in a freight house where every conceivable variety of package must be handled from any one of several different points to any one of numerous other points, they are not satisfactory. Where they have been installed they have sometimes been practically a dead loss. It is cheaper and quicker to push a loaded truck on and off an elevator, than to unload it into a chute or conveyor, and then reload the freight onto another truck at the other end.

These three possible means of handling freight between two levels are unsatisfactory. The fourth method, namely, the use of elevators, remains, and is the only one found during this investigation which commends itself as generally suitable for use in freight houses. It lends itself particularly well to the handling of L.C.L. freight, as it involves practically no rehandling, and because either a two-wheel truck or a four-wheel truck can be put through the elevator equally well, although

the four-wheel truck, as it has a greater carrying capacity, is the better vehicle. A trucker can handle 800 or 1,000 lbs. on a four-wheel truck as easily as 200 or 300 lbs. on a two-wheel truck, for the former does not tax his strength in lifting and supporting part of the load, and allows him to put all of his effort into pushing the truck. Elevators are flexible (need only be run when necessary), safe, reliable, can be designed so as to have a large capacity, and are cheap in operation.

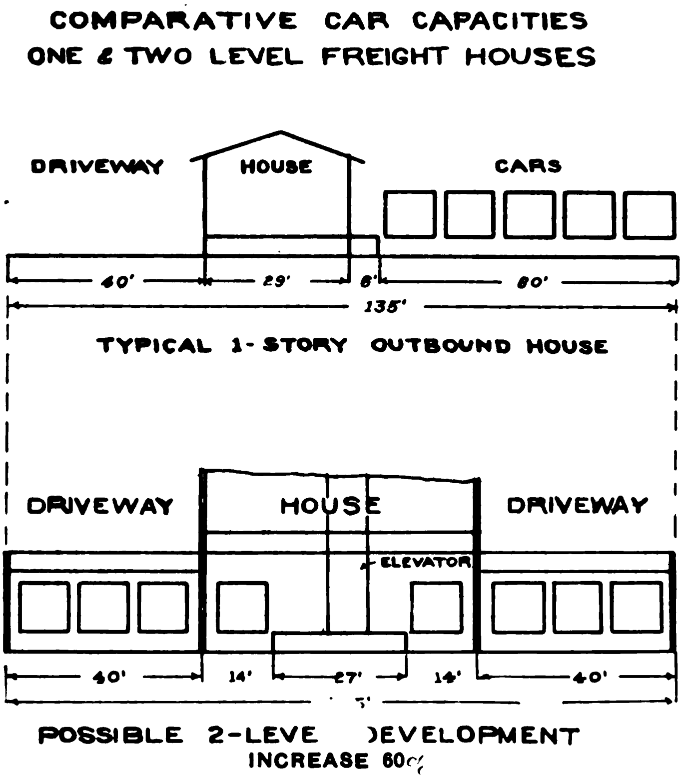


FIG. 3.

The elevator should be wide enough to carry a loaded four-wheel truck or "dolly" and long enough to hold four or five of them in a row, the trucks being placed at right angles to the long side of the elevator, thus obtaining a high capacity per trip of the elevator and permitting the handling of articles of unusual dimensions. To fill these conditions the necessary dimensions would be about 8 ft. by 20 ft. Standard elevators are built with a speed of 50 ft. and 100 ft. per minute. Either speed is suitable, for the limiting point is not the time between floors, but the time at each floor, and unless the elevator is

designed to permit rapid loading and unloading, its efficiency will be seriously crippled. The higher-speed elevators can make each trip quicker, but free movement on and off at each floor is more important than speed between floors. In order to obtain rapid handling, access to and from the elevator should be had from the long side, preferably from both, and at each floor. Observations of elevators in existing two-

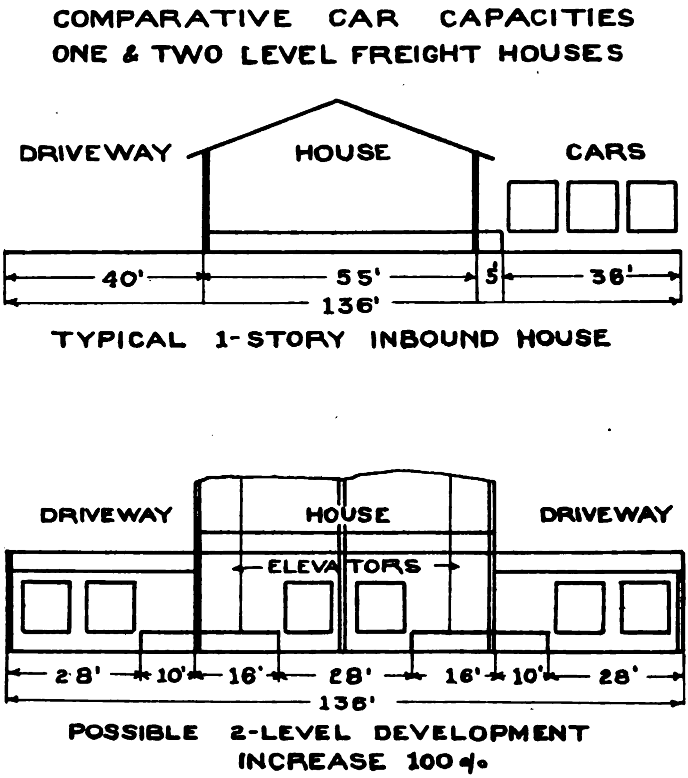
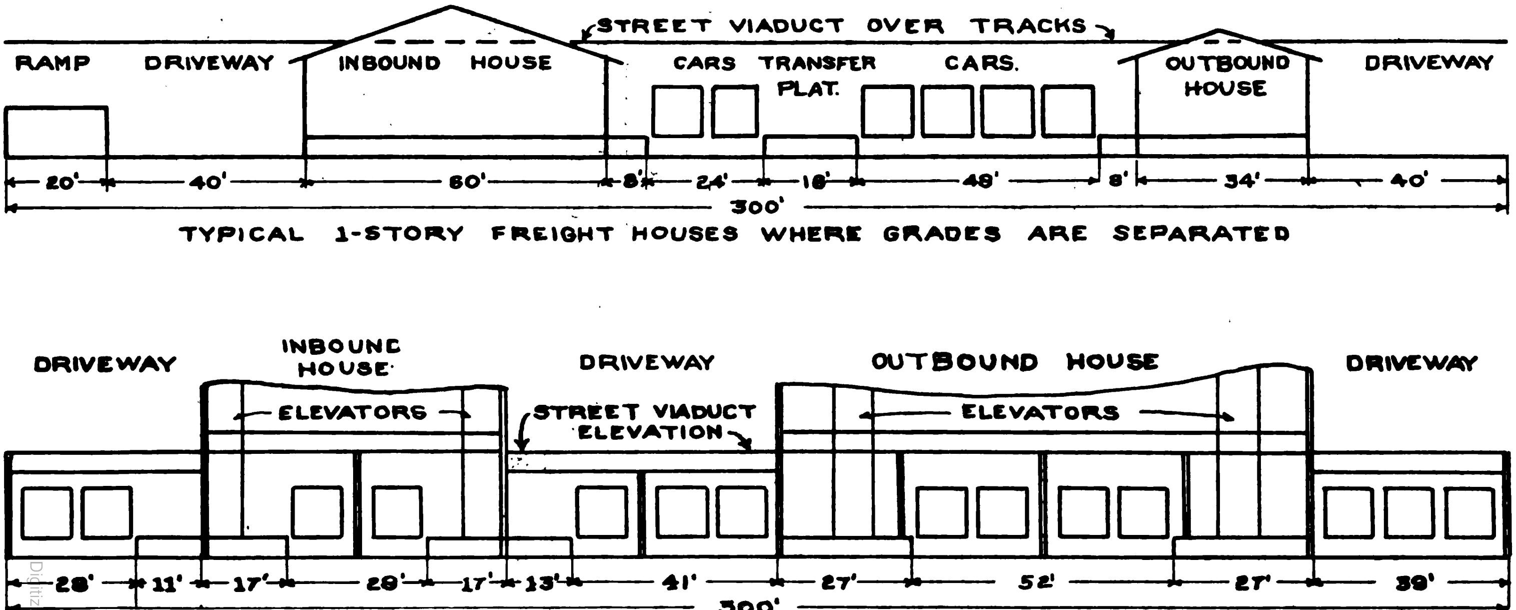


Fig. 4.

level houses have shown that such an elevator can be unloaded and reloaded in about 60 seconds.

The capacity per elevator can then be estimated as:

> Minimum: Load to five two-wheel trucks at 200 lbs. per truck, average time for round trip three minutes (one way empty trucks only), capacity per hour .... 10 tons.
>
> Maximum: Load of five four-wheel trucks at 1,000 lbs. per truck, average time per round trip, 2½ minutes (one way empty trucks only), capacity per hour .... 60 tons.



POSSIBLE 2-LEVEL DEVELOPMENT

INCREASE 133 %

Fig. 5.

A fair average per elevator per hour, in existing houses, has been found to be 20 tons, capable of being speeded up to 60 tons in rush periods.

The cost of operation of elevators is low, averaging one to two cents per ton for power, and a little less for labor (attendant). In addition to the actual cost of operation, however, there is some extra trucking, as there would be some lost motion.

It is estimated that these costs (in a well-designed house) will be:

Power and maintenance	1½ cents
Labor (elevator man)	1 cent
Delay to truckers	1½ cents
Total	4 cents per ton

An examination of existing freight-house elevators has shown this to be very closely correct. Table 5 gives the costs of operation of several two-level houses, and an estimate of the cost of elevators. This varies from two to ten cents per ton, depending largely on the design and size of the elevators and platforms, and the method of operation. When the elevators are so small as to hold only one or two trucks at once, when the platforms are so narrow as to cause congestion, or when freight is unloaded from the trucks into the elevator as if it were a box car, and reloaded onto other trucks at the other end, the cost per ton is high. But when the elevators are of ample capacity, designed to permit rapid loading and unloading, and the platforms are of sufficient width and the trucks themselves (but not the truckers) are sent through them, the cost of elevation is as low as two or three cents per ton. Four cents a ton is believed to be a conservative estimate for a well-designed house.

If the saving in the necessary length of a house is sufficient to reduce operating costs 4 cents per ton, the decrease in operating costs will balance the elevator cost; any decrease in operating costs due to any greater decrease in the length of the house will be clear profit. Thus, if for houses over 400 ft. long the cost of operation increases 1 cent for every 35 ft. increase in length of house, and a single-story house would have to be 800 ft. long to have a capacity of 100 cars, and a double-deck house of the same capacity only 400 ft. long, the saving in operation under the assumptions made would be $\frac{400}{35} = 11.4$ cents per ton, minus the cost of elevation, of 4 cents per ton, or a net saving of 7 cents per ton. Assuming an average loading of 6 tons per car and 300 working days a year, the annual operating saving would be $.07 \times 6 \times 100 \times 300 = \$12,600$.

Therefore, when ground is worth over $4.50 per sq. ft., a two-level freight house means a smaller total investment than a one-level house, and when the saving in the length of the house is more than 140 ft., which would be the case in all houses over 400 ft. in length, there will

be a decrease in operating costs. From either the investment or the operating standpoint in these cases a two-level house is, therefore, a more desirable type than a one-level.

Furthermore, there are the sometimes desirable advantages of separating grades, improving the street system and adding to the convenience of the freight house for shippers, all of which indirectly add to the volume of business which will be obtained, and may therefore tend to decrease operating cost.

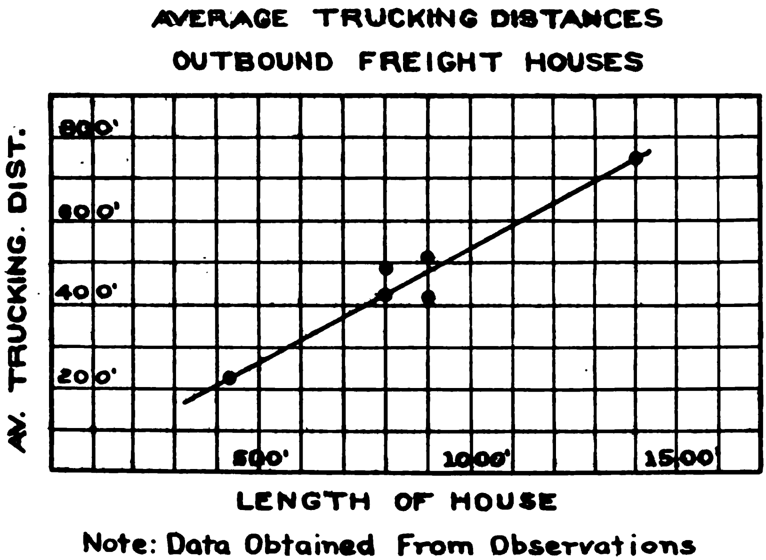


FIG. 6.

There are several two-level houses now in use, although so far as known none were built in order to decrease interest charges or operating expenses, but because owing to local conditions one-level houses could not readily have been built. Detailed data regarding seven of these are given in Table 5. There are a few others, but the writer has not yet been able to examine them. Most of the present two-level houses having been designed primarily to meet local conditions, have not obtained the full advantages of two-level construction, but nevertheless some decrease in interest charges and operating costs has resulted.

A still further decrease in fixed charges is desirable, if possible. This may be obtained by building storage or warehouse floors above the freight house. This can be done equally well in one or two-level houses. It decreases fixed charges, and gives the tenants excellent shipping facilities. There is a danger in this practice, however; tenants do not handle all their freight over their landlord's line; they require and

receive a great deal of switching service to and from other lines, for which the landlord line receives only a nominal switching charge. Moreover, they are often slow in loading and unloading freight, frequently holding cars for several days. A car held four days, switching revenue $5, plus $2 demurrage, does not add to profits; if it displaces a car each day at a loss of revenue of from $40.00 to $50.00 per car. To sum up, while overhead storage or warehouse floors decrease fixed charges, yet the requirements of tenants may be such as to seriously diminish the ultimate capacity of the freight house, although possibly leases can be drawn which will eliminate the above objections.

Where the overhead space can be used for light manufacturing or office purposes, the above objection may not hold true; nor when the contents of warehouses are held during long periods, and for city consumption; but this phase of the question merits the most careful consideration.

CONCLUSIONS.

Summing up, we draw the following conclusions from the foregoing:

The L. C. L. freight business of large cities is growing rapidly. The need for enlargement is becoming more pressing. The investment required is constantly becoming heavier. The obstacles to one-level expansion are becoming more severe. The removal of transfer freight to outlying points provides only temporary relief from congestion. More rapid handling of the business in many cases requires too radical a change in local shipping customs. Mechanical handling, even if economical, has but slight effect on capacity. Double-decking, by decreasing both the investment per car and the operating expense, and as it also adapts itself to grade separation, is a logical method of improvement. Its adoption for city L. C. L. freight terminals may, therefore, be expected to become more general, as conditions demand.

TABLE No. 1.—COMPARISON OF INVESTMENT PER CAR AND INTEREST CHARGES PER TON OF SINGLE AND DOUBLE-DECK FREIGHT HOUSES FOR DIFFERENT LAND-VALUES

Value of Land per sq. ft.	One-Level 2,000 sq. ft. per car		Two-Level 1,300 sq. ft. per car		Two-Level 1,000 sq. ft. per car	
	Investment per car	Interest per ton	Investment per car	Interest per ton	Investment per car	Interest per ton
$ 1	$4,000	$0.111	$6,500	$0.175	$5,000	$0.139
2						
3						
4						
5	12,000	0.333	11,700	0.325	9,000	0.250
6						
7						
8						
9						
10	22,000	0.611	18,200	0.506	14,000	0.389
11						
12						
13						
14						
15	32,000	0.889	24,700	0.686	19,000	0.528
16						
17						
18						
19						
20	42,000	1.167	31,200	0.866	24,000	0.667

Note.—For one-level houses the ground area per car is assumed to be 2,000 sq. ft. and the value of the improvement to be $2,000 per car ($1.00 per sq. ft.).

For two-level houses the ground area per car is assumed to be 1,300 sq. ft. and the value of the improvement to be $5,200 per car ($4.00 per sq. ft.).

In many cases, however, double-decking would decrease the ground area to 1,000 sq. ft. per car, at which area the value of the improvements would be $4,000 per car ($4.00 per sq. ft.).

Interest charges per ton are computed on the basis of 300 cars per annum and six tons per car.

TABLE No. 2.—FREIGHT HOUSE DATA

Collected from 58 Freight Stations of 24 Railroads Located in 17 Cities

Reference No.	Type	Length: Actual Feet	Length: Used Feet	Width Feet	No. of Tracks	Width Driveway Feet	Tons per Month	Cars per Month	Cost per ton, Cents
1	Trap Cars.	....	....	....	....	30	6,113	500	15.3
2	Trap Cars.	....	....	....	....	30	3,256	315	11.9
3	In. & Out..	53	53	26	1	Street	133	....	13.0
4	In. & Out..	52	52	39	1	St.	440	....	9.1
5	In. & Out..	60	60	30	1	St.	300	....	14.0
6	In. & Out..	100	100	22	1	St.	1,040	140	12.5
7	In. & Out..	130	130	35	1	St.	504	84	14.0
8	In.........	192	192	27	1	St.	3,230	164	19.5
9	In. & Out..	200	200	30	1	St.	1,280	150	17.9
10	In. & Out..	241	210	31	1	60	2,900	....	18.6
11	In. & Out..	250	250	....	....	....	3,000	....	21.2
12	In.........	371	371	40	4	40	5,040	1,100	25.0
*13	In. & Out..	375	375	152	4	40	9,000	900	24.1*
14	In.........	380	380	40	3	St. + 25	1,950	350	42.3
15	In. & Out..	400	400	60	2	St.	7,800	1,100	18.7
16	Out.......	550	400	42	5	42	8,800	1,100	31.0
17	In.........	410	410	37	4	50	....	....	25.0
*18	In. & Out..	417	417	73	4	36	2,400	600	24.9*
19	Out.......	430	430	30	6	60	5,000	....	36.9
*20	In. & Out..	380	440	118	6	50	4,500	1,000	30.0*
21	In. & Out..	700 200	450	....	3	St.+	4,060	1,000	29.0
22	In.........	500 444	470	60 42	3 1	70	5,500	1,020	43.6
*23	In. & Out..	480	480	80	5	35	10,000	1,800	25.0*
24	In. & Out..	480	480	44	4	St.	11,080	2,025	36.0
25	In.........	500	500	40	2 & 3	66	13,750	925	34.0
26	Transfer...	500	500	24	7	None	16,160	986	25.7
27	In. & Out..	510	510	50	3	66	6,400	1,100	33.9
*28	In. & Out..	400	540	232	7	38	3,400	600	30.0*
*29	In. & Out..	535	535	100	4	28	13,800	1,300	21.2*
30	In.........	540	540	73	2	50	....	....	37.0
31	Transfer...	640 250	550	35 25	7	None	10,500	1,600	25.0
32	Out.......	564	564	50	7 & 8	50	13,400	2,050	30.7
33	In. & Out..	570	570	....	8	35	18,400	....	23.6
34	Out.......	600	600	50	5	....	9,500	....	42.4
35	In. & Out..	600	600	30	4	66	10,400	....	36.0
36	Out.......	600	600	30	4	....	....	....	36.0
37	In.........	600	600	....	3	St.+	3,976	600	34.0
38	In.........	640	640	60	2	50	8,400	1,600	47.2
39	Transfer...	600 725	650	16	6	None	10,000	1,650	34.6
40	In. & Out..	890 620	700	45 30	5	....	14,200	3,000	39.0
41	In. & Out..	705	705	60	5	St. + 20	15,300	1,600	28.0
42	Transfer...	800	700	16	10	None	22,500	3,500	30.5
43	In. & Out..	750	750	28	3	35	3,150	....	40.0
44	Out.......	1,750	900	11-24	1, 2 & 4	35	19,100	2,050	43.1
45	Out.......	780	780	27	4	66	12,500	1,530	45.6
46	Out.......	800	800	30	5	St. + 10	14,400	2,126	47.0
47	Out.......	800	800	30	4	50	17,500	....	43.0
48	Transfer...	800	800	16	9	None	19,135	2,800	41.9
49	In.........	090	800	60	3	50	13,300	1,600	42.4
50	In.........	815	815	61	2	40	5,500	1,250	46.0
51	In.........	840	840	40	2	....	17,500	....	43.0
52	Transfer...	986 800	890	14 12	9	None	15,000	2,550	45.5
53	Transfer...	1,270 1,020 300	880	18 & 20	12	None	31,000	5,000	48.0
54	Transfer...	900	900	50	....	None	12,500	....	47.5
55	Out.......	1,045	900	30	3 & 4	St. + 25	11,600	1,325	45.4
56	Transfer...	976	976	30	8	None	9,600	1,765	45.8
57	Out.......	1,700	1,300	50	3	St. + 17	12,000	2,500	57.7
58	Out.......	1,600	1,400	28-40	7	70	31,000	5,750	62.4

*Indicates a two-level house (all using elevators).

Note.—"Actual" length is the actual length of the house. Where part of the house is unused; where the house is operated in two sections; where there are two or more platforms of different lengths; or where the house is very wide, the "Actual" length has been increased or decreased to a fair "Used" length. Where there are separate warehouse floors the operating "Cost Per Ton" as given does not include the cost of storage.

TABLE 3.—ITEMIZED OPERATING COSTS

Outbound Houses

House Number	46	44	55	19	58	47
Overhead	6.3	5.4	7.57	4.40	2.10	4.09
Receiving	16.7	14.1	13.22	11.44	20.02	15.06
Trucking	20.5	16.4	18.77	15.01	33.00	18.07
Stowing	3.05	7.2	6.85	6.01	7.26	5.76
Total	47.0	43.1	45.41	36.86	62.38	42.97

Inbound Houses

House Number	50	49	14
ver head	10.07	3.42	11.54
Receiving	10.04	13.40	12.34
Trucking	16.20	12.90	11.33
Delivery	9.70	9.77	7.07
Stowing	.....	2.91	.....
Total	46.04	42.40	42.28

Combined Houses (In and Out.)

House Number	*24	*41
Overhead	2.9	3.58
Receiving	15.4	15.50
Trucking	21.8	22.25
Delivery	6.2	.....
Stowing	2.6	2.43
Total	48.9	43.80

*Cost of operating warehouse floors included.

Note.—House numbers correspond to reference numbers given in Table 2.

TABLE 4.—RELATIVE FACILITIES OF SOME EXISTING FREIGHT HOUSES

Outbound

House Number	44	46	55		57	45
Length of house	1,360 ft.	900 ft.	1,045 ft.	1,150 ft.	1,700 ft.	780 ft.
Width	24 ft.	30 ft.	30 ft.	30 ft.	42 ft.	27 ft.
Effective length	750 ft.	800 ft.	900 ft.	40 ft.	1,300 ft.	780 ft.
Number tracks	3 & 4	5	3 & 4	2	3	6
Car capacity	136	90	134	60	125	84
Cars per day	106	85	53	90	100	61
Ratio cars per day to car cap	78%	94%	39.5%	150%	96%	72.6%
Width driveway	35 ft.	St.+10 ft.	St.+25 ft.	....	St.+	St.
Driveway frontage	850 ft.	640 ft.	610 ft.	1,150 ft.	1,600 ft.	780 ft.
Driveway frontage per car cap	8.0 ft.	7.5 ft.	4.6 ft.	19.2 ft.	12.8 ft.	9.3 ft.
Platform area, sq. ft	32,000	19,200	27,000	34,500	....	21,000
Platform area per car capacity, sq. ft.	232	213	219	570	....	251
Tons per month	19,100	14,400	11,600	13,500	12,000	12,500

Inbound

House Number	50	49	14		22	38
Length of house	815 ft.	990 ft.	380 ft.	1,300 ft.	440 ft.	640 ft
Width of house	61 ft.	60 ft.	40 ft.	48 ft.	60 ft.	60 ft.
Effective length	815 ft.	800 ft.	380 ft.	40 ft.	440 ft.	640 ft.
Number tracks	2	3	3	2	3	3
Car capacity	50	75	27	60	33	34
Cars per day	50	63	14	73	....	44
Ratio cars per day to car cap	100%	84%	52%	120%	....	130%
Width driveway	40 ft.	50 ft.	St.+25 ft.	St.+	St.+	St.
Driveway frontage	960 ft.	990 ft.	350 ft.	1,300 ft.	440 ft.	640 ft.
Driveway frontage per car capacity	19.2 ft.	13.2 ft.	13.0 ft.	21.7 ft.	13.0 ft.	18.8 ft.
Platform area, sq. ft.	54,000	59,400	14,000	72,800	79,200	36,000
Platform area per car capacity, sq. ft.	1,080	792	520	1,210	2,400	1,060
Tons per month	5,500	13,320	1,950	5,800	....	8,400

Note.—House numbers correspond to reference numbers given in Table 2.

TABLE 5.—DATA ON DOUBLE-DECK FREIGHT HOUSES

Reference No.	13	18	20	23	28	29	
Length, Actual.	375 ft.	417 ft.	380 ft.	360 ft. + 120 ft. plat	400 ft.	535 ft.	357 ft.
Used...	375 ft.	417 ft.	440 ft.	480 ft.	540 ft.	535 ft.	
Width..........	152 ft.	73 ft.	118 ft.	80 ft.	232 ft.	100 ft.	145 ft.
Type of House..	In. & Out.	In. & Out.	In. & Out.	In. & Out.	In. & Out.	In. & Out.	In.
First Level.....	Out.	Out.		Out.			
Tracks.......	4	4	None	5	7	None	None
Platforms..	2-27 ft. x 375 ft. 2- 6 ft. x 375 ft.	1-28 ft. x 415 ft.	1-41,500 sq. ft.	1-27 ft. x 480 ft.	1-27 ft. x 400 ft.	3-45 ft. x 150 ft.	1-25,800 sq. ft.
Driveways...	1-40 ft. x 375 ft.	1-30 ft. x 415 ft.	2-50 ft.	1-35 ft. x 360 ft.	None	2-27.5 ft. x 435 ft.	1-18,100 sq. ft.
Second Level...	In.	In.		In.		2nd & 3rd Floors	
Tracks.......	None	None	6	None	None	Storage	6
Platforms....	2-55 ft. x 375 ft.	1-73 ft. x 415 ft.	2-18 ft. x 400 ft. 1-18 ft. x 480 ft.	1-80 ft. x 360 ft.	2-83 ft. x 232 ft. 2-42 ft. x 215 ft.	100 ft. x 535 ft.	5-25,400 sq. ft.
Driveways...	1-40 ft. x 375 ft.	1-36 ft. x 417 ft.	None	1-35 ft. x 360 ft.	4-38 ft. x 232 ft.		None
Upper Levels...	None	2 Stor. Floors	None	1 Stor. Floor	Office only	4th Level	4 Stor. Floors
Tracks.......		28,244 sq. ft.		80 ft. x 360 ft.		4	52,000 sq. ft
Platforms....		Each				1-45 ft. x 535 ft.	Each
Driveways...						1-25 ft. x 100 ft. None	
Type of System	Elevators and Hand Trucks	Elevators and Hand Trucks	Elevators and Hand Trucks	Elevators and Hand Trucks	Elevators and Hand Trucks	Elevators and Hand Trucks	Elevators and Hand Trucks
No. of Scales...	11	10	..	....	....	....	13
Elevators							
Size..........	4-9 ft. x 15 ft. 2 Ton	4-8 ft. x 9 ft. 5 Ton 1-9 ft. x 15 ft. 10 Ton	5-6 ft. x 14 ft. 6 1-7 ft. x 22 ft. 6 Ton	5-10 ft. x 17 ft.	4-8 ft. x 18 ft.	4-9 ft. x 14 ft. 5 Ton 1-10 ft. x 20 ft. 10 Ton	7-7 ft. x 10 ft. 3 Ton 2-8 ft. x 12 ft.
Power........	Hydraulic	Electric	Electric	Hydraulic	Electric	Hydraulic	Electric
Speed........	60 ft. per Min.	50 ft. per Min.	50 ft. per Min.			1-20 ft. per Min.	
No. of 2-Wh. Tr.	30	....	73	125	....	56	....
No. of 4-Wh. Tr.	150	None	14	125	....	228	....
Car capacity....	36	32	66	60	57	43	43
Cars per day...	36	24	40	72	24	48	75
Ratio........	100%	75%	60%	120%	42%	112%	173%
Team Frontage.	1,500 ft.	830 ft.	635 ft.	720 ft.	1,632 ft.	870 ft.	680 ft.
Per Car Cap..	41 ft.	26 ft.	9 ft. 6 in.	12 ft.	38 ft. 6 in.	20 ft. 5 in.	15 ft. 4 in.
Platform Area..	53,400 sq. ft.	37,800 sq. ft.	64,200 sq. ft.	41,000 sq. ft.	63,718 sq. ft.	46,260 sq. ft.	51,200 sq. ft
Per Car Cap..	1,270 sq. ft.	1,175 sq. ft.	972 sq. ft.	683 sq. ft.	1,118 sq. ft.	1,075 sq. ft.	1,190 sq. ft
Tons per Month.	9,000	2,400	4,500	10,000	3,400	12,800	....
Tons per Car...	9	3.8	4.5	5.6	5.7	10.7	....
Cost per Ton							
Receiving....	5.5c	11.0c	3.5c	Not	Not	2.57	Not
Trucking.....	12.1c	8.5c	15.0c	Reported	Reported	9.43c	Reported
Stowing......	4.4c	4.9c	7.1c				
Delivery.....	...	7.3				5.23c	
Overhead....	2.1	3.3	4.4				
Elevators.....						3.95	
Total.....	24.1c	35.0c	30.0c	35.0c	39.0c	21.18c	
Est. Cost Elev.	7.0c	4.0c	10.0c	2.0c	4.0c		9.0c

Note.—This information was obtained by personal examination of the above seven houses owned by seven railroads and located in six large cities. All seven are using elevators to handle freight between different levels. The reference numbers correspond to those used in Table 2

TABLE 6—TRUCKING DISTANCES IN OUTBOUND HOUSES IN CHICAGO; TOTAL FROM DOOR TO CAR AND RETURN FROM OBSERVATIONS.

House Reference Numbers	Length Actual	Length Used	Trucking Distance
19	430	430	220
44	1750	900	439
46	800	800	480
47	800	800	430
55	1045	900	515
58	1600	1400	750

Average Trucking Distance = 53 per cent. of the length of the house.
NOTE—Reference numbers are the same as given in Table 2.

TABLE 7—COMPARATIVE FACILITIES ONE AND TWO-LEVEL FREIGHT HOUSES, FIGS. 3, 4, 5.

	Driveway Frontage Per Car. Feet.	Driveway Area Per Car. Sq. Ft.	Platform Area per Car. Sq. Ft.
Outbound House, Fig. 3—			
One-Level	8	333	280
Two-Level	10	380	410
Inbound House, Fig. 4—			
One-Level	13.3	533	800
Two-Level	13.3	507	760
In and Outbound Houses, Fig. 5—			
One-Level	13.3	533	853
Two-Level	11.4	377	800

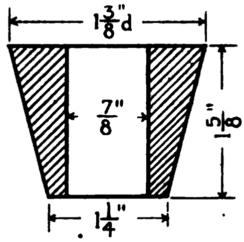
SUPERSTRUCTURE WITH CAST-IRON CHAIRS.

. Extract from an Article by E. C. W. van Dyke, Chief Engineer, Central Dutch Railway.

The above article appears in full in "Organ für die Fortschritte des Eisenbahnwesens" for December 1, 1912.

In 1912 the Central Dutch Railway introduced a track superstructure. between Utrecht and Amersfoort, in which the rails were fastened to the wooden cross-ties by means of cast-iron chairs. The chair weighed about 28.1 lbs. (13 kg.) and has a base measuring 14$\frac{3}{16}$ by 6$\frac{7}{8}$ in. (360 by 175 mm.).

The chair is fastened to the tie with four screw spikes, $\frac{7}{8}$-in. in diameter by 8$\frac{1}{4}$ in. long (23 by 210 mm.). The holes for the screw spikes in the chair are lined with wooden filler rings, driven in with wooden mallets just before the screw spikes are placed, this being done to prevent any play in the holes.



The support for the rail in the chair is 3$\frac{3}{16}$ by 4$\frac{11}{16}$ in. (80 by 120 mm.), of which surface but 1$\frac{3}{16}$ in. is level, while the rest (1 in. on each side) is beveled, for the purpose of eliminating the tilting of the ties.

The rails are fastened to the chair by means of clips and bolts with nutlocks. These bolts are put in from the side, instead of from the bottom, as is usually done.

The rails weigh about 93 lbs. per yard, and are 59 ft. long, and are of the following dimensions:

Base of rail	4$\frac{3}{4}$ in.
Height	5$\frac{5}{8}$ in.
Width of top of head	2$\frac{11}{16}$ in.
Width of bottom of head	3 in.
Fishing angle	1 in 4
Fishing contact	$\frac{33}{32}$-in.

The angle bars are 31$\frac{1}{2}$ in. long, with four holes, and use 1-in. bolts.

Twenty-four wooden ties per 59-ft. rail are used. These cross-ties are 6$\frac{5}{16}$ by 10$\frac{1}{4}$ in. by 8 ft. 9 in. long, and are impregnated with 22 lbs. of tar oil (System, Rueping). The joint ties are spaced 17$\frac{3}{4}$ in. center to center. All ties are adzed to give level bearing surface for the chairs.

The advantages of the chairs are as follows:

(1) Better distribution of the rail pressure on the ties, as compared with rails resting on thin rolled tie plates.

(2) The chairs can be fastened to the ties before placing the ties in the track.

(3) Damaged bolts can be easily renewed without disturbing the chairs.

(4) The height of the chairs permits the covering of the ties with ballast.

(5) Experiments and tests have shown that the chairs do not break under a load of 40 tons (under this load, however, the chair cuts into the tie from $\frac{3}{8}$ to $\frac{13}{16}$-in.).

This chair superstructure is cheaper than the English rail chair construction with bullhead rails and is slightly more costly than the standard superstructure with ordinary tie-plates, as shown below:

COST OF SUPERSTRUCTURE (INCLUSIVE RAILS AND TIES) PER YARD.

Standard with the Ordinary Tie Plates.	English Chairs with Bullheaded Rails.	New Chair Type.
$4.83	$5.49	$5.16

The Central Dutch Railway maintains a shop where the chairs are fastened to the ties. In connection with this work it is of interest to note that the holes for the screw spikes are not bored clear through the tie, but only to within about $\frac{3}{4}$-in. of the underside.

The writer is of the opinion that the present standard superstructure, with ordinary tie plates, is inefficient for the present-day requirements.

The destruction of ties increases very rapidly and has to be checked with new appliances.

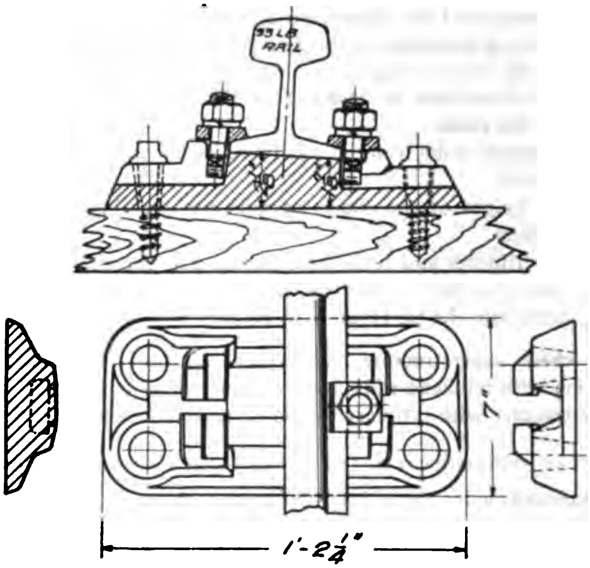
It is important that the fastening of the chair to the tie be distinctly separate from the fastening of the rail to the chair. The chair should also be of such dimensions that the material will not be subjected to pressure beyond the elastic limit.

Upon recommendation of the writer, the Central Dutch Railway built, in 1909, for experimental purposes, a track of the English type, i. e., bullheaded rails fastened with wooden wedges in cast-iron chairs, these latter being held to the wooden ties by means of screw spikes.

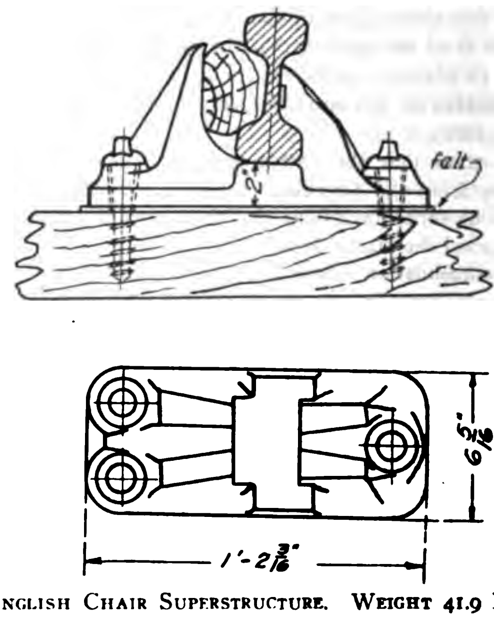
The results of this experiment were satisfactory. In three years' time no measurable cutting of the ties by the chairs could be found. No tightening of the screw spikes was found necessary.

It has been established that planing of the ties at the chair seat sufficed even on softwood ties and that shims of fiber or wood were unnecessary.

The protection of the wood is so good that we find the life of ties in the main tracks on English railroads to be about 21 years, and that these ties fail by decay and not wear, while on Dutch railroads of standard construction (ordinary tie plates) the life of ties is only about 14 years.



CAST-IRON CHAIR. WEIGHT 28.7 LBS.



ENGLISH CHAIR SUPERSTRUCTURE. WEIGHT 41.9 LBS.

The rail joints are in fair condition, although the tie spacing is quite wide. The bolts are tight. The joints are, however, a little weak. Measurements taken every three months showed no changes in the gage.

The wooden wedges proved unsatisfactory. In dry and warm weather the wedges became loose, thus permitting the rails to creep, and anti-creepers had to be applied, which increased the cost.

Imported English wedges were not seasoned and showed considerable shrinkage after one year's seasoning. Perfectly seasoned wedges gave better results, but their sensitiveness to moisture is a serious matter.

The experience with the English chairs induced the writer to design a chair suitable for Vignol rails.

The rail base is approximately the same as the English. The fastening of the rail was accomplished by clips and bolts, to be put into place from the top and then turned 90 degrees.

This track was laid in 1910.

Although the chairs (22 lbs.) were put upon unplaned ties with "knotty" structure, laid in a very bad ballast, with a tie spacing of 39 in., the superstructure gave good service. Not one chair was broken and the clip bolts were all tight after 20 months' service, although no nut-locks were used.

The placing of the clip bolts for above may become difficult, if the holes become clogged, and replacing a broken bolt is not always easy.

We found that the rails on these chairs do not creep.

On this particular track we used 19-year-old rails, with badly-worn joints. The chairs at the joints were, therefore, under very severe conditions.

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